2020 AAPT VIRTUAL SUMMER MEETING

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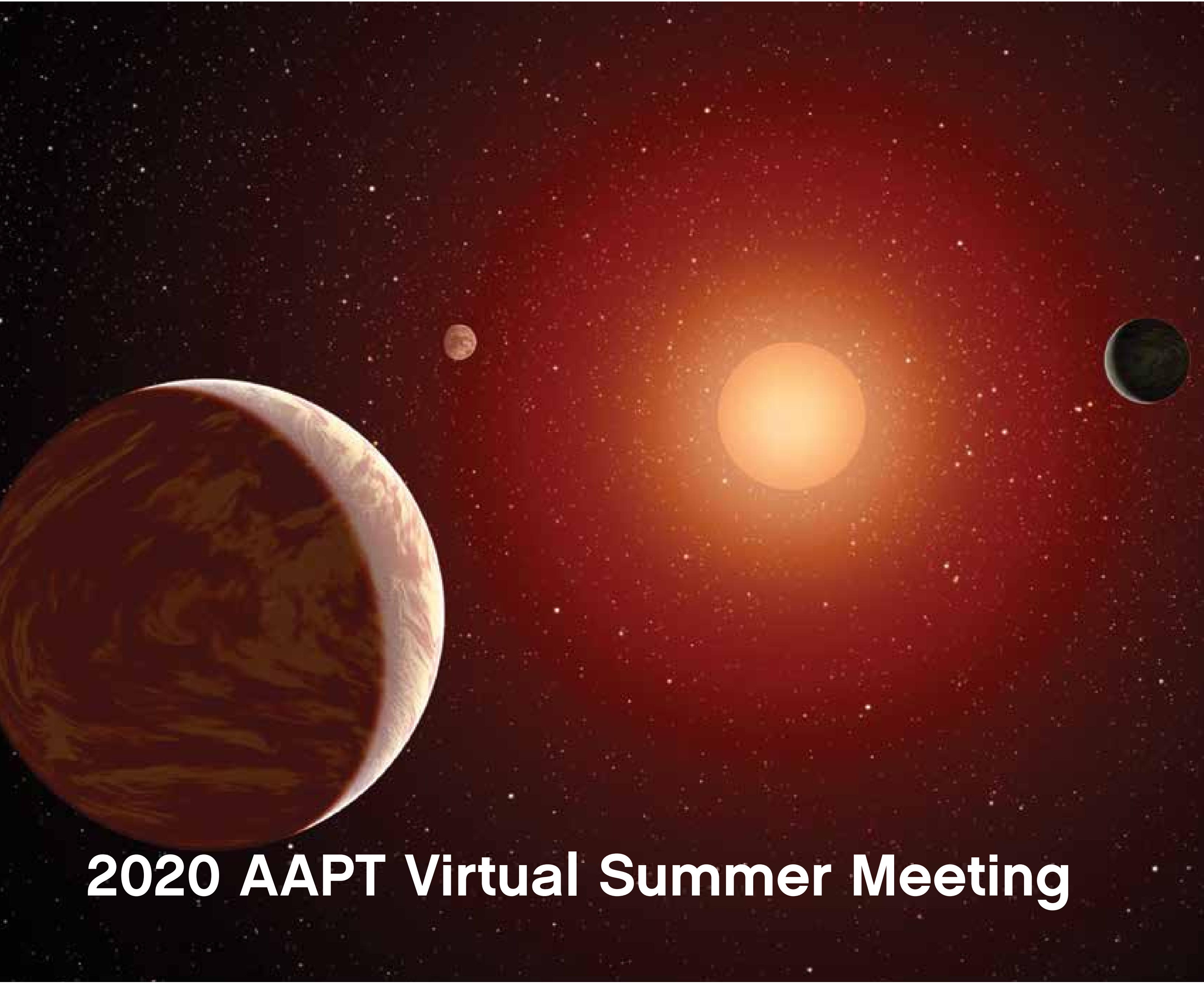

2020 AAPT Virtual Summer Meeting

July 19–22, 2020

AAPT PHYSICS EDUCATION®

American Association of Physics Teachers®

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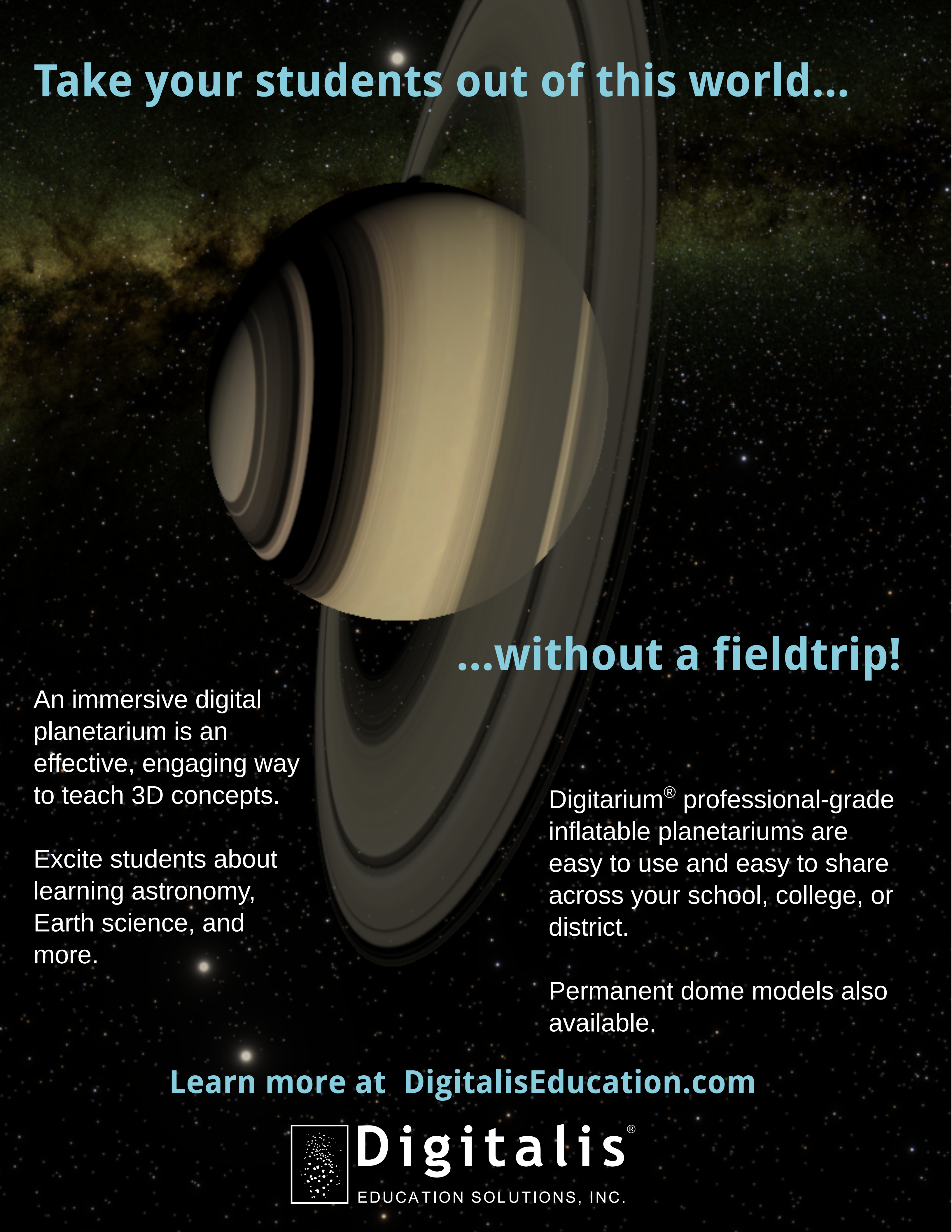
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NSF SBIR Phase I: <u>Educational Technologies and Applications. July, 2019.</u>

Computer Science for All with Spreadsheet Modeling: Researching How Low-Cost Video Training for STEM Teachers Leads to High-Value Programming Skills for Students.

Submitted by Spreadsheet Lab Manual LLC, Michael McConnell, Principle Investigator

Abstract for the 116th Congress of the United States of America:

This SBIR Phase 1 Project will seek to solve the problem of how to incorporate new and standardized approach to computer science instructional modeling experiences for students using a combination of video training, instructional materials, and assessment materials that can be accessed by teachers from an online platform to which teachers can contribute newly developed ideas for authorship credit and compensation. Models that simulate realistic behavior are usually inherently complex using mathematics such as calculus or differential equations. As a result, many teachers do not recognize the many possible ways that these models can be developed on spreadsheet programs. While teachers and students already can access and have baseline familiarity with spreadsheets, there exists many new computational modeling applications that can fundamentally change the nature of the way students learn Science, Technology, Engineering and Math (STEM) as separate subjects by unifying them into one instructional modeling experience. This study will develop and investigate methods of training inexperienced teachers in computational spreadsheet modeling that are designed to enable easy to follow pathways for teachers to deliver spreadsheet modeling experiences to their students with in-person training or having to develop and test their own student experiences. This will serve to expand the use of computer science in classrooms in compliance with the Next Generation Science Standards (NGSS) and open up the realistic modeling capability intrinsic to calculus and differential equations, to high school students while using exclusively algebraic equations.

This proposal will seek to develop, adapt, and assess the effectiveness of an inexpensive video-based demonstration and teacher training regimen that is intended to make delivering this instructional methodology to students happen quickly, efficiently and become self-sourcing by teachers from many different schools. This will be done by automating the training to keep cost to a minimum and maximize teacher time savings and the value added of the modern microprocessor to the student instructional experience of computational modeling on a spreadsheet. For a typical spreadsheet modeling objective, students follow procedures employing numerical methods (such as slope of lines, areas of trapezoids, difference equations, Euler's Method) incrementally over large numbers of cells (10^2-10^4) to build a realistic mathematical model on a spreadsheet. By doing this, the error associated with the numerical approach drops well below the error associated with model assumptions making it possible to model non-ideal continually changing variables with linearized assumptions. The computational power of the spreadsheet enables instantaneous replication of the linearized formulas, which when patterned properly with fixed and relative references, can produce pivot tables in which variables can be altered by students using inquiry and curiosity to investigate a model that they programed starting from a blank spreadsheet. By building off of a variety of curriculum aligned applications and crafting the instructional experience using a carefully tested pedagogy, teachers will be provided with high value skills to pass on to their students so they will be able to first program, then simulate, experiment and solve problems on a variety of new quantitative spreadsheet modeling scenarios in STEM classes.

National Science Foundation Small Business Innovation Research (NSF SBIR)

<u>SLM Member Educators</u>: Develop, Deliver, Share, Get Paid.

K12 PHYSICS TEACHERS LOUNGE

Digi Kit labs for hands on virtual instruction

Topical discussions

STEP UP promoting women to pursue Physics

Sunday July 19

The Grand Challenge
12:30pm-1:30pm

Distance Learning lesson share out
1:30pm-2:30pm
When we start in the fall, will we still be doing distance learning? Be prepared, and bring a lesson to share at the K12 distance learning lesson plan share out.

STEP UP
2:30pm-3:00pm
Join a fact exploration and discussion on the NSF grant STEP UP physics together aiming to drastically increase the number of women in undergraduate physics through interventions in the high school classroom.

Topical discussion: Teaching as a second career
3:00pm-3:30pm
Thinking about switching to K12 teaching? Have you already switched to K12 teaching? Come ask your questions and share your stories!

What I Wish I Knew
3:30pm-4:30pm
Listen as early career teachers give short background presentations on each of their unique pathways into teaching and an overview of the teacher preparation programs.

Monday July 20

Advocating for my Physics Program
12:30pm-1:30pm
Teacher leader Melissa Grimscheid will share how she doubled physics enrollment at her school and increased enrollment across the district.

Get The Facts Out
1:30PM-2:30pm
Join an exploration of unexpected trends in the data on educators in the United States while discussing perceptions of STEM teaching in society.

HS Physics Share Out
2:30PM-3:30pm
Bring your most engaging lesson to share at the high school lesson plan share out!

Presidents Town Hall
3:30PM-4:30pm

AAPT PHYSICS EDUCATION

Tuesday July 21

Quantum Computing in the Lounge
12:30pm-1:00pm
AAPT has established Quantum Computing Education as one of its four BIG IDEAS for program development.

Topical Discussion:Equity and Inclusion
1:00PM-1:30pm
A discussion of challenges and successes on how we as educators meet the needs of all students in the classroom.

Panel Discussion: Student Perception on distance learning
1:30PM-2:30-pm
Hop on in for a panel discussion on how HS students perceived the effectiveness of online learning.

2:30PM-3:30-pm
Racial Justice in Physics Class
How can we, as physics teachers, play a part in efforts for racial justice that go beyond representation? We will share ideas, including an exploration of the Under representation Curriculum, and discuss steps we can take next year.

Thank You to AAPT's Sustaining Members

The American Association of Physics Teachers is extremely grateful to the following companies who have generously supported AAPT over the years:

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Special Thanks

AAPT wishes to thank the following persons for their dedication and selfless contributions to the 2020 Summer Virtual Meeting:

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Janie Head
Nina Daye Morley
Karen Jo Matlser
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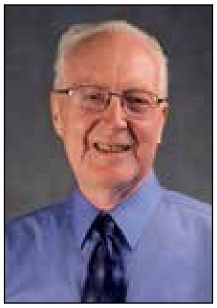
Facebook/Twitter at Meeting

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 **#aaptsm20**. We will also be posting any changes to the schedule, cancellations, and other announcements during the meeting via both Twitter and Facebook. We look forward to connecting with you!

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



David M. Cook

"Attempting the (seemingly) Impossible"

Wednesday, July 22
11 a.m.–12:30 p.m.

2020 Millikan Medal Awarded to David Cook

AAPT has announced that David M. Cook will receive the Robert A. Millikan Medal during the 2020 Summer Meeting. Cook is a pioneer in computational physics education and has rendered extraordinary service to AAPT on Area Committees, the Meetings Committee, AAPT representative to AIP Governing Board, and in the Presidential Chain. He has organized a computational physics conference and led computational curriculum education projects. He has been an AAPT member since 1966.

Cook received BS in physics in 1959 from Rensselaer Polytechnic Institute. His AM (1960), and PhD (1965) degrees in physics were both earned at Harvard. In 1965, he joined the Department of Physics at Lawrence University, now a 1500-student liberal arts college in Appleton, WI, advancing from Assistant (1965-71) to Associate (1971-79) to Full (1979) Professor of Physics and to Philetus E. Sawyer Professor of Science (1989), and receiving the Lawrence Excellence in Teaching Award in 1990.

Starting in the early 1980s, he and his colleague, John Brandenberger, committed themselves to building a strong undergraduate department that now has five full-time faculty members, graduates an average of ten physics majors each year, was a case-study department at the 1998 AAPT/APS/AIP revitalization conference, and was included among the exemplary departments reviewed in the SPIN-UP study. Cook retired from full-time teaching and research in June 2008 but maintains an office at Lawrence University and is engaged in several writing projects. Cook's research interests lie in computational physics, musical acoustics, and uses of computers in the upper-division physics curriculum.

Between 1988 and his retirement in 2008, with support from two grants from the NSF (1988, 1993), three grants from the W. M. Keck Foundation (1988, 1994, 2002), and Lawrence University, Cook directed an extensive curricular development project that has created a departmental environment in which physics majors become expert at using state-of-the-art computing resources intelligently and independently. In support of this endeavor, he built the Lawrence Computational Physics Laboratory, which, is currently equipped with 12 Linux workstations that make numerous software packages for graphical visualization, numerical analysis, and symbolic algebra available to students 24/7. The project attracted national attention and has been described in several publications and in invited talks given by Cook at several national meetings, colleges and universities. In February, 2000, he received an NSF grant supporting the assembling of the extensive instructional materials developed at Lawrence into a flexible and customizable textbook titled Computation and Problem Solving in Undergraduate Physics, which was completed in January, 2003, continues to be used at several colleges around the country, and is now available for free download from ComPADRE. That NSF grant also supported the holding of four week-long summer workshops that brought a total of 70 college faculty members from around the United States for an intensive exposure to the way in which Cook helps Lawrence students become skilled in the use of computational resources.

ABSTRACT: For years, I have posted on the wall of my office a slightly paraphrased quotation that is credited to John Stuart Mill: "Students who are never required to do what they think they cannot do never discover what they can do." Confidently attempting the (seemingly) impossible is an important component of individual—and I think also of departmental—growth. Students' growth is damped if they are never gently nudged to attempt the impossible. Departmental growth is limited unless the department regularly undertakes coordinated ambitious activities that may initially seem unlikely to succeed. My own department at Lawrence provides my case study. As Metropolitan opera star Beverly Sills once said, ``You may be disappointed if you fail, but you are doomed if you don't try."

Just before his retirement in June of 2008, Cook was elected Vice-President of the American Association of Physics Teachers, serving successively as Vice-President, President-Elect, President, and Past President. His four-year term came to an end in February of 2012. In that capacity, he has also served on several AAPT Advisory Committees, as chair of the AAPT Review Board, Awards Committee, and Committee on Governance Structure. and as AAPT representative to the AIP Governing Board, the APS Council, the APS/FEd Nominating Committee, and the APS/FEd Executive Committee. In January 2013, he embarked on a three-year term as chair of the AAPT Meetings Committee. (see full bio at aapt.org Programs/awards/millikan.cfm)

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. Self-nomination is not appropriate for this award. Preference in the selection of the recipient will be given to members of AAPT.

2020 Klopsteg Memorial Lecture Award Given to James Kakalios

James Kakalios

Superheroes and Public Outreach (No Spandex Required)

Sunday, July 19
12:30–1:30 p.m.

AAPT has announced that James Kakalios, University of Minnesota, Minneapolis, MN, is the 2020 recipient of the Klopsteg Memorial Lecture Award. The lecture and award will be presented during the AAPT Summer Meeting.

Kakalios received his PhD in 1985 from the University of Chicago. He is the Taylor Distinguished Professor in the School of Physics and Astronomy at the University of Minnesota, where he has taught since 1988. His scientific research in experimental condensed matter physics concerns the properties of complex and disordered systems. His class "Everything I Needed to Know About Physics I learned from Reading Comic Books" is a popular freshman seminar.

Extensive media coverage of this class in May 2002, in connection with the release of the first Sony Spider-Man film, resulted in hundreds of e-mails from students, teachers and those long out of college, all supporting the concept of using superheroes to teach physics and enquiring about a book based on the class. This led to his writing the popular science book *The Physics of Superheroes* (2005) that has been translated into six languages, and whose Spectacular Second Edition was published in 2009. He is also the author of *The Amazing Story of Quantum Mechanics* (2010) and the recently published *The Physics of Everyday Things* (Crown, 2017).

In 2007, he served as the science consultant for the Warner Bros. superhero film Watchmen. He appears on the DVD version of the film in a special feature that discusses some of the science behind one of Watchmen's central characters — Dr. Manhattan. In 2009, Kakalios made a video with the University News Service on "The Science of Watchmen," which has been viewed over 1.8 million times and in 2009 won a regional Emmy Award in the "Advanced Media: Arts/Entertainment" category. In 2012, Kakalios served as one of the science consultants for the Marvel Entertainment American superhero film The Amazing Spider-Man. A 2018 video for Business Insider, where Kakalios discussed the physics underlying 10 Iconic Scenes in Marvel superhero movies has been viewed over 4.2 million times, and another for Science Insider on the strength of Spider-Man's webbing has received over 530,000 views.

His research interests include nanocrystalline and amorphous semiconductors and fluctuation phenomena in neurological systems. His efforts at science outreach have been recognized with awards from the American Association for the Advancement of Science and the American Institute of Physics. Kakalios has been recognized by the American Institute of Physics with the 2016 Andrew Gemant Award. The American Association for the Advancement of Science (AAAS) recognized him with their award for Public Engagement with Science in 2014 and as an AAAS Fellow in 2013. He was named as a Fellow by the American Physical Society in 2015.

ABSTRACT: Costumed superheroes seem to dominate our movie and television screens, making them an excellent delivery system to bring real physics to students and the general public. While the super-powers these characters possess clearly violate the laws of nature, often times how the super-heroes and super-villains utilize their powers is consistent with known physical laws. One can therefore leverage the public's interest in these characters to illustrate and explain the physics principles that underlie their fantastic adventures. A discussion of the strength of Spider-Man's webbing can lead to the real physics of carbon nanotubes. What metal would be strong enough for Wonder Woman's bullet deflecting bracelets? One can draw the connection between the Black Panther's vibranium suit and conservation of energy, while the Infinity Stones (the MacGuffin in 22 Marvel Cinematic Universe films) can be connected to Emmy Noether and her theory explicating a deep connection between all conservation principles and symmetries in the laws of physics. People come for the superhero ice cream sundae and stay for the real science. If superheroes can help explain physics and the benefits of research in the classroom and to the general public – well, it wouldn't be the first time these heroes have saved the day!

In nominating Kakalios for this award his colleagues noted, "Using comic books and superhero movies as a "hook," Jim Kakalios has found a unique way to relate physics to the public, in a fun and accessible manner."

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.

Ann Walkup

Paul W. Zitzewitz Award for Excellence in K-12 Physics Teaching – Ann Walkup

The 2020 Paul Zitzewitz Excellence in K-12 Physics Teaching Award winner is Ann Walkup, a physics teacher at Cranston High School East, Cranston, Rhode Island. Educated at Connecticut College with a BA in Physics and an MA in Physics Education, she became a life member of AAPT in 2002. Walkup was a member of the Rhode Island Department of Education (RIDE)/ Charles Dana Education Center (University of Texas at Austin) Next Generation of Science Standards science curriculum writing team for six years. She has been instrumental in translating the NGSS into a viable and rigorous physics curriculum for both Cranston Public School Students and the Students of Rhode Island. Her work on curriculum includes the writing of our Foundations for Physics scope and sequence and the units of study. This year, she is a member of the STEAM committee at Cranston High School East (CHSE). Their focus is to collaborate with teachers from different departments to develop units and lessons that integrate Science, Technology, Engineering, Art, and Mathematics, and to make these lesson available to all the CHSE community.

Through her impeccable lesson planning and forms of assessment Walkup has helped many students in the Cranston Public Schools acquire the necessary skills to engage in the study of physics. Her dynamic approach to the teaching of physics allows all students from myriad backgrounds to excel in physics. She has instructed a diverse student body in multiple levels of courses from early enrollment, to honors, to independent studies, to comprehensive, to self-contained courses for students with special needs. She is a champion of STEM teaching and her delivery and style should be emulated by all physics educators.

Walkup currently co-teaches the CHSE Ballroom Dance club and is a member of USA Dance, as well as a certified Bob Ross Instructor in oil painting. She also plays harp and has performed with the CHSE orchestra. In 2012, she founded the Robert and John L. Walkup Scholarship, an annual award given for excellence in physics, in memory of her father and uncle. She is a previous winner of the 2008 AMGEN Award for Science Teaching Excellence. Currently, she is working towards a Graduate Colored Stones degree from the Gemological Institute of America.

Let's All Do Physics!: Integrating Special Education Accommodations in Physics Curriculum.

Monday, July 20
1:30–2:30 p.m.

ABSTRACT: Cranston High School East is both the largest and most diverse high school in Rhode Island according to US News and World Report, with 60% minority students and 46% economically disadvantaged. Many are transient, have unconventional families, do not speak English, or have mental/physical disabilities. Many would think these students incapable of learning physics. This is a travesty; anything can be taught once you find common ground.

I take the time to learn students' stories, connect with their backgrounds, and make what I teach relevant to their lives. I enable them to feel successful and confident in their abilities. I find common ground and make physics concepts relatable on their terms. The vocabulary in many textbooks is unapproachable because many students are reading below grade level. Even glossaries use convoluted terminology in definitions. Books and technology can be intimidating; not every student is technology-savvy. Despite all that, no student is unteachable; they just need to be better understood by their teacher. As physics teachers, we need to teach the students in front of us, tailor what we are teaching to what they need to learn, and most importantly, teach them to be curious lifelong learners.

Established as the Excellence in Pre-College Teaching Award in 1993 then renamed and endowed in 2010 by Paul W. and Barbara S. Zitzewitz, the Paul W. Zitzewitz Award for Excellence in Pre-College Physics Teaching recognizes outstanding achievement in teaching pre-college physics.

David Halliday and Robert Resnick Award for Excellence in Undergraduate Physics Teaching – Deborah Mason-McCaffrey

Deborah Mason-McCaffrey

Deborah Mason-McCaffrey will receive the 2020 David Halliday and Robert Resnick Award for Excellence in Undergraduate Physics Teaching. This award is given in recognition of contributions to undergraduate physics teaching and awardees are chosen for their extraordinary accomplishments in communicating the excitement of physics to their students. John Wiley & Sons is the principal source of funding for this award, through its donation to the AAPT.

Mason-McCaffrey is Associate Professor, Department of Chemistry and Physics, Salem State University, Salem, Massachusetts. She earned her B.S.M.E. in Mechanical Engineering, with highest distinction, at the University of Rhode Island, her Sc.M. in Solid Mechanics at Brown University, and her Ph.D. in Theoretical & Applied Mechanics at Cornell University.

She is the Chair of the Undergraduate Research Symposium Committee at Salem State, the immediate Past-President of the New England Section of the American Association of Physics Teachers (AAPT), and an AAPT Fellow. Prior to teaching at Salem State, she worked as an engineer in product development and as a department manager at Polaroid Corporation, followed by several years as a consultant and trainer. Mason-McCaffrey's interest is in understanding the link between mathematics preparation and students' conceptual gains in introductory physics.

In nominating her for this award her colleague said, "Dr. Mason-McCaffrey achieves teaching excellence. Despite teaching rigorous courses, her student evaluations are consistently outstanding. Her course materials, including her syllabi, are meticulously organized. Her use of student-active learning techniques, such as in-class group problem solving, videos, applets and Interactive Lecture Demonstrations (ILDs) is to be commended. In addition to experimenting with various student-active learning techniques, she assesses her methods using pre- and post-testing. Dr. Mason-McCaffrey has played a critical role in reviving the Physics Minor at Salem State and puts in countless hours personally interacting with potential and current students."

Should Engineers be Teaching Physics?

Tuesday, July 21
1:30–2:30 p.m.

ABSTRACT: There are a significant number of engineers teaching Physics at the secondary level. There are data to quantify that. The data are sparse, however, when we ask how many engineers teach physics in 2-year, 4-year, and R1 institutions. If the technology allows, we will take a quick look into that question by polling meeting attendees.

So, should engineers be teaching physics? My answer is a qualified 'Yes.' We'll examine a few pros and cons, and some stereotypes. We would be wise to acknowledge that engineers are, indeed, trained to think differently than physicists, which influences our approaches to problem-solving. We also know that teaching can involve things that are difficult to measure; such as building rapport, respect and community. I would like to show how those un-measurables, in concert with my experiences as an engineer, have shaped my approach to teaching physics. I try to balance careful planning and structure, with flexibility and treating teaching as a prototype product that can be continuously improved. And, finally, I will talk about being part of the significant growth in the Physics minor at Salem State University (Massachusetts).

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.

PIRA Virtual Family Physics Demonstration Extravangza

Tuesday, July 21
4:30 p.m. (EDT)
via Zoom

Homer L. Dodge Citations for Distinguished Service to AAPT

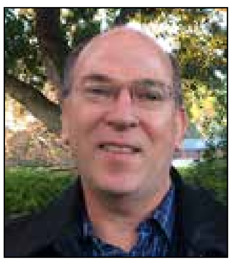
Douglas Brown

Douglas Brown

Wednesday, July 22
11 a.m.–12:30 p.m.

Douglas Brown is Physics Professor Emeritus, Cabrillo College, Aptos, California. In retirement, he continues to actively support Tracker, the free video analysis and modeling tool he developed as part of the Open Source Physics project. A member of AAPT since 1991, he has been recognized for teaching excellence and served as department chair at Cabrillo. He is currently a resource editor for the Tracker collection in the ComPADRE digital library. Tracker is widely used in the physics community with over 1 million downloads. It has been translated into 26 languages and it is regularly cited in *The Physics Teacher*, with 81 citations for the original 2009 Tracker paper (Vol **47**, p 145). Brown's interest in video analysis started in the early 1990s and led him to begin developing Tracker during a sabbatical leave in 2001. In 2002 he joined the Open Source Physics project, ensuring that Tracker would be freely available and widely disseminated. Since then, Tracker has become a powerful video analysis tool with automatic tracking and the ability to analyze videos that tilt, pan, zoom or have skewed views of the action. Brown also added spectroscopic analysis to Tracker, going beyond the capabilities of traditional video analysis programs. Tracker includes a data tool so students can easily fit theoretical curves to their data. In 2007 Brown extended Tracker beyond video analysis by provided a modeling tool as well. Students build dynamic particle models that move according to Newton's laws, then overlay the models on videos to directly compare them to the real world. This allows teachers to include basic computational physics at the introductory level with very little instructional overhead. Tracker is used in popular physics forums as well for outreach to the general public. FBrown has given Tracker-based talks and workshops at regional, national, and international meetings and has published articles on video analysis and modeling in *TPT* and other journals.

Dan Burns



Dan Burns

Dan Burns taught Advanced Placement Physics and Earth/Space Science at Los Gatos High School in Los Gatos, California for 27 years. He is currently the physics curriculum and training specialist at PASCO scientific in Roseville, CA. An active member of AAPT since 1994, Burns is an active member of the Northern California/Nevada AAPT Section and has served as President of the Section. He conducts the PTSOS workshop program, now in its 16th year. Burns has also taught workshops and wrote curriculum for many different organizations including Lawrence Livermore National Laboratory, USGS, the SETI Institute, and the National Math and Science Initiative. His reach has been extensive and he has helped many physics teachers better understand their content and implement better curriculum. He understands that supporting the teacher supports the students. In an age of packaged and purchased curriculum Burns gives many of his resources freely to his peers. He does not mind spending the time to help a teacher, knowing that it will improve their course for not only this year's students but all of those in the future. He feels a sense of responsibility to pass on the knowledge it has taken him years to gain to make the road a bit easier for those that follow. Burns is quite the showman, employing elaborate props and demonstrations that both illustrate and entertain. His YouTube channel helps not only students but teachers to fully understand the intricacies of seemingly simple problems.

Plenary

Acoustics: A Model for Interdisciplinary Research & Teaching in Physics

Andrew Barnard, Michigan Technological University

Andrew Barnard

Sunday, July 19
10:30–11:30 a.m.

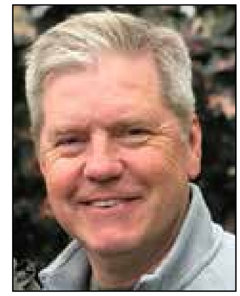
What gets students excited for STEAM careers? In my experience, it is interdisciplinary subjects that can spark interest in students of all backgrounds. I entered the field of Acoustics because it was so interdisciplinary. Acoustics is a core area of physics, but also fills knowledge areas in mechanical engineering, electrical engineering, mathematics, biology, arts, theater, medicine, computer science, and other disciplines. A background in acoustics is a broad introduction to the physical principles of science and engineering. In this talk, I will share insights from my interdisciplinary program in acoustics from both a research and teaching perspective. Anecdotes from the classroom will be presented as well as overviews of varied interdisciplinary research topics from underwater sensing to carbon nanotube speakers. I will share my passion for the field of acoustics and show how it transitions into the success of students on many, varied career paths.

Dr. Andrew Barnard is an associate professor of Mechanical Engineering – Engineering Mechanics and Director of the Great Lakes Research Center at Michigan Technological University. He holds a BS and MS in mechanical engineering from Michigan Technological University and a PhD in Acoustics from Penn State. Dr. Barnard is Board Certified by the Institute for Noise Control Engineering (INCE) and is a Certified LabVIEW Developer (CLD). He is currently the Vice President for Education of INCE and an associate editor for Noise Control Engineering Journal (NCEJ). He previously spent 8 years as a research associate at the Applied Research Laboratory at Penn State. Dr. Barnard has interests in mechanical vibration, noise control, and acoustics. His specialties include dynamic test and measurements, remote sensing, signal processing, and real-time control systems. Dr. Barnard is the advisor and founder the SENSE program (Strategic Education through Naval Systems Experiences) at Michigan Tech and is the advisor of the Naval Systems Engineering Minor. He was awarded the Distinguished Teaching Award at Michigan Tech in 2019. His research has led to the publication of 34 peer reviewed articles and conference proceedings and 82 non-refereed publications and presentations. In addition to teaching and research, he works on commercialization of technology and is a founder or co-founder of three companies.

APS Plenary:

The Physics of Green Energy

Wolfgang Bauer, Michigan State University

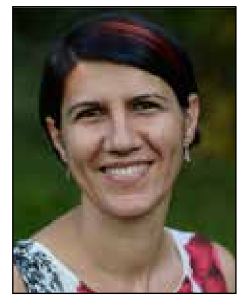


Wolfgang Bauer

The near-exponential increase of greenhouse gas emissions due to human activity and the associated global warming are established facts. At present, humans consume approximately 20 TW of average power, overwhelmingly supplied by fossil fuels. What does it take to supply this amount of power from renewable resources? There are physical limitations (Betz Limit, Shockley-Queisser Limit, storage cycle efficiency, raw materials constraints, …), but there are also economic and financial ones. This presentation will try to give a global perspective as well as a local perspective, with the campus of Michigan State University as a sample of what has been, what can be, and what needs to be accomplished.

Nuclear Science: Rare Isotopes at FRIB and What to do With Them

Artemis Spyrou, Michigan State University



Artemis Spyrou

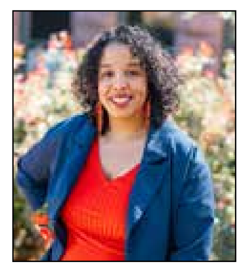
Nuclear Science as a field has been around for more than 100 years. Many of its mysteries have already been explored, but there are still important open questions that the field is trying to address even today. One of the big questions is how neutrons and protons combine together to form bound systems (isotopes) and what are the properties of each combination. At Michigan State University (MSU) there is a 50-year history of producing and studying the rarest of these isotopes. Some can be used for practical applications for the benefit of society, and others live for fractions of a second and are only important in explosive stellar processes. The next generation rare isotope laboratory for the US, the Facility for Rare Isotope Beams (FRIB) is currently under construction at MSU. FRIB is expected to give us access to roughly 1000 new isotopes, never before created or studied in a lab. In this talk I will discuss how rare isotopes are produced at FRIB and the important scientific questions that FRIB will address. I will also present resources that were developed by the facility's outreach team to help scientists and teachers bring the science of FRIB into the hands of students of any age.

Tuesday, July 21
11 a.m.–12:30 p.m.

Moderator: Jan Mader

Plenary Session: Intersectionality and Transdiciplinarity in Physics Education

Mildred Boveda, Arizona State University, Mary Lou Fulton Teachers College



Mildred Boveda

Recent studies raise awareness of the nature of diversity and inclusivity concerns and propose best practices for reducing bias for women, LGBTQ+ students, racially/ethnically minoritized students,, and students with disabilities in physics education. While considering individual sociocultural categories (e.g., gender) in isolation has its merit, it is insufficient to adopt a unidimensional approach when attempting to address the disparities in representation and opportunities in physics. Instead, the simultaneous influence of multiple sociocultural identities such as age, gender, citizenship, class, dis/ability, ethnicity, linguistic origin, and sexuality must be considered. Faculty must also examine how interconnected sociocultural identities—their own, those of students, and of other educators—influence curricular decisions and pedagogical practices, as well as power dynamics in the classroom. Scholars in equity-based education communities (e.g. bilingual and special education), ethnic studies, and women, gender, and intersectional studies can inform how physics educators may collaboratively locate and address biases in curriculum and pedagogical practices, including those related to overlapping and interconnected oppressions. Intersectional consciousness will thus be present as a collaborative approach to advancing intersectionality and transdisciplinarity in physics education.

Mildred Boveda is an assistant professor of special education and cultural and linguistic diversity at the Mary Lou Fulton Teachers College. In her scholarship, she uses the term intersectional competence to describe teachers understanding of diversity and how students, families, and colleagues have multiple sociocultural markers that intersect in complex and nuanced ways. She designed the Intersectional Competence Measure to assess teachers‘ preparedness for an increasingly diverse student population. Her research focuses on establishing the theoretical and empirical evidence of validity of the intersectional competence construct. Drawing from Black feminist theory and collaborative teacher education research, she interrogates how differences are framed across education communities to influence education policy and practice.

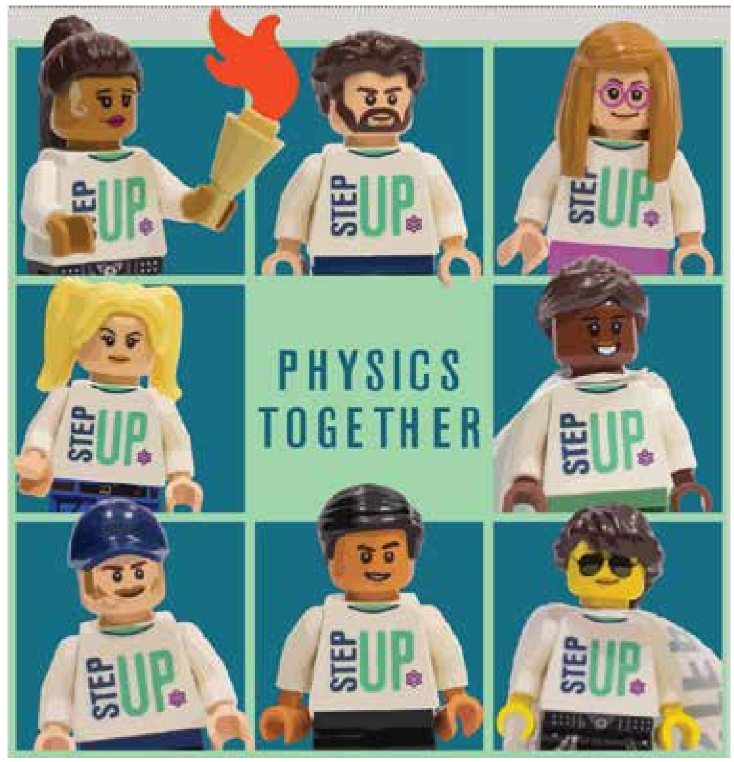
Monday, July 20
10–11 a.m.

Presider: Jan Mader

PLENARY SESSION: STEP UP: A Social Movement to Promote Cultural Change in Physics

Zahra Hazari, Florida International University
Bree Barnett Dreyfuss, Amador Valley High School
Colleen Epler-Ruths, Shikellamy High School
Brian Kays, Ramona Convent Secondary School
John Metzler, Niles West High School
Laura Sloma, East Kentwood High School and Freshman Campus

Monday, July 20
11 a.m.–12:30 p.m.



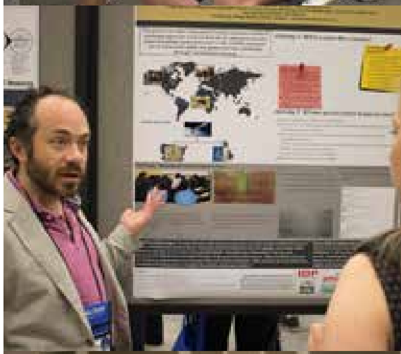
Physics, as a field, is developed and maintained by a community, and thus reflects historic and modern cultural norms set by that community, both consciously and unconsciously. This includes how physics is defined, what it means to do physics, and what it means to be a physicist. In order to shift cultural meanings to be more inclusive and equitable, we need to reflect on the norms and collectively work to disrupt those norms that marginalize groups and limit advancement. One approach is to pose counternarratives that disrupt narrow stereotypic viewpoints. Counternarratives are central to the STEP UP project, which focuses on mobilizing thousands of physics educators to inspire young women in physics. STEP UP presents counternarratives to students through lessons/materials that explicitly discuss the role of bias in the field and highlight a broad range of careers/goals pursued by diverse individuals with a physics degree. Another counternarrative is presented through the agents of change who lead the movement – teachers. In a culture that undervalues teachers and teaching as a profession, a powerful counternarrative is that teachers can collectively affect cultural change. Given this framing, the presentation will feature Zahra Hazari, the plenary speaker, as well as teachers who are helping to lead the way: Bree Barnett Dreyfuss, Colleen Epler-Ruths, Brian Kays, John Metzler, and Laura Sloma.

SPEAKER BIOS: *Zahra Hazari* is a Professor in the Department of Teaching and Learning and the STEM Transformation Institute as well as an affiliate faculty member in the Department of Physics at Florida International University. *Bree Barnett Dreyfuss* is the STEP UP Ambassador Program Coordinator leading 80 Ambassadors in our second year. *Colleen Epler-Ruths* and *Brian Kays* are two of our seven Ambassador Leads. *John Metzler* is a STEP UP Ambassador and Master Teacher. Brian and John have also been AAPT/AIP Master Teacher Policy Fellows. *Laura Sloma* is serving a second year as a STEP UP Ambassador.

Committee Meetings at the 2020 AAPT Summer Meeting

All committee meetings will be held virtually at the times listed below.
Times are shown using Eastern Daylight Time (EDT)

	Time	Chair
Friday, June 26		
Committee on Physics in High Schools	9–11 a.m.	Reed Prior
Tuesday, July 7		
Review Board	3–4 p.m.	Mel Sabella
COGS	4–5:30 p.m.	Mell Sabella
Thursday, July 9		
Awards (closed)	3–4:30 p.m.	Mel Sabella
Monday, July 13		
Committee on Laboratories	12:30–2:30 p.m.	Troy Messina
Committee on Professional Concerns	12:30–2:30 p.m.	Jennifer Blue
PER Leadership Organizing Council	12:30–2:30 p.m.	Geoff Potvin
Finance (closed)	3–5 p.m.	Thomas O'Kuma
ALPhA Committee	5:30–7:30 p.m.	Heather Lewandowski
Committee on Diversity in Physics	5:30–7:30 p.m.	Arlene Modeste Knowles
Tuesday, July 14		
Committee on Space Science and Astronomy	10 a.m.–12 p.m.	Ken Brandt
Publications Committee	10 a.m.–12 p.m.	D. Blane Baker
Committee on the Interests of Senior Physicists	12:30–2:30 p.m.	David Donnelly
Committee on Physics in Two-Year Colleges	3–5 p.m.	Glenda Denicolo
Committee on Research in Physics Education	5:30–7 p.m.	Trevor Smith
Wednesday, July 15		
Committee on Contemporary Physics	10 a.m.–12 p.m.	Deborah Roudebush
Executive Programs	11 a.m.–1 p.m.	Jan Mader
Committee on Apparatus	3–5 p.m.	Stephen Irons
Committee on Graduate Education in Physics	3–5 p.m.	Daniel Doucette
Committee on Physics in Undergrad Education	3–5 p.m.	Marie Lopez del Puerto
Committee on Women in Physics	3–5 p.m.	Sathya Guruswamy
PTRA Oversight	4–6 p.m.	Jill Marshall
Committee on Physics in Pre-High School Education	5:30–7 p.m.	Shawn Reeves (time & day change)
Meetings Committee	5:30–7:30 p.m.	Mary Mogge
Thursday, July 16		
Committee on History & Philosophy in Physics	3–5 p.m.	Joanna Behrman
PhysicsBowl Advisory https://zoom.us/j/93734687761	5–7 p.m.	Jon Anderson
Committee on International Physics Education https://zoom.us/j/92617622131	5:30–7:30 p.m.	Kathleen Ann Falconer
Friday, July 17		
Fredrick and Florence M. Bauder Endowment (closed)	10 a.m.–12 p.m.	Thomas O'Kuma
Programs and Planning I https://zoom.us/j/95397165038	12–2 p.m.	Toni Sauncy
Membership and Benefits https://zoom.us/j/94792136205?pwd=M3ljblNNRmNiWVRIVGpxODVIbWZHdz09	2–3:30 p.m.	David Sturm
Committee on Educational Technologies https://zoom.us/j/91565150411	3–5 p.m.	Brandon Lunk
Committee on Science Education for the Public https://zoom.us/j/98552062206?pwd=YkRWVU9VZ21jd1FQdXV1VzFiSktzZz09	3–4:30 p.m.	Tatiana Erukhimova
Committee on Teacher Preparation https://wakeforest-university.zoom.us/j/6751511637?pwd=KzJnaytEYW4yUmlPcVhyUk5XZmU0dz09	5:30–7:30 p.m.	Debbie French
Nominating Committee (closed)	5:30–7:30 p.m.	Dwain Desbian
Saturday, July 18		
Board of Directors Meeting (closed)	9 a.m.–5 p.m.	Chandralekha Singh
Thursday, July 23		
Section Officers Exchange https://maine.zoom.us/j/95870085854?pwd=SjFxclNJMUdIOG8yY3Q2ZzVyQXBnUT09 Password for above link: 125338	3:30–4:30 p.m	David Sturm
Section Representatives/Alternates Meeting	4:30–5:30 p.m.	David Sturm
Friday, July 24		
Committee on Physics in Pre-High School Education (special planning meeting) https://zoom.us/j/99411479244?pwd=QXFlTHdMTFhjNGM5TjhoZVVKN2owUT09	5–6:30 p.m.	Shawn Reeves
Wednesday, July 29		
Programs and Planning II https://zoom.us/j/92965627661	12–2 p.m.	Toni Sauncy



A number of workshops that were previously scheduled for the 2020 AAPT Summer Meeting in Grand Rapids will be offered virtually. Please see the list below. Times are EDT.

Cost: All workshops four hours and under will cost $50 for members and $100 for non-members. All workshops over four hours will cost $80 for members and $160 for non-members.

CEU Hours: Earn CEU hours for attending one of the AAPT workshops. Earn 0.40 hours for a 1/2 day workshop or 0.80 for a full-day workshop.

Workshops, Friday, July 10

W05: Astronomy Research Seminar

DATE: Friday, July 10 Time: 9:00 AM to 1:00 PM (EST)

Organizer: Rachel Freed

Participants will learn how to conduct an Astronomy Research Seminar, including how to use online tools to select a project, how to use the Las Cumbres Observatory and Skynet Telescope Networks to collect data, and the analysis software and methods. This will be a hands-on workshop, where each participant will use their own computer to go through the whole process. There will also be a discussion of the process whereby students are taught how to write for scientific publication. After the workshop, online support will be provided to help participants start their own Astronomy Research Seminar with the end goal being to have students submit their own research papers for publication.

W10: Classroom Activities with Black Holes in LIGO Data

DATE: Friday, July 10 Time: 1:00 PM to 4:00 PM (EDT)

Organizer: Jonah B. Kanner/Co-Organizer: Amber Stuver

Do you want to hear what it sounds like when black holes collide? This workshop will show you how you can use gravitational wave observations in your physics classroom. LIGO and Virgo are currently observing mergers of binary black holes and binary neutron stars. These events – and the signals they produce – can be connected to a range of introductory physics concepts, including wave mechanics, circular motion, Newtonian gravity, and conservation of energy. LIGO and Virgo – the world's leading gravitational wave observatories – make their data publicly available through a web portal. Bring your laptop, and we'll use python scripts to download and plot real gravitational-wave signals. Then we'll explore the physics curriculum learning outcomes that can be demonstrated through these exciting astrophysical events. Workshop take-aways will include activities you can use in class appropriate for both high school or college physics students.

W34: Developing the Next Generation of Physics Assessments

DATE: Friday, July 10 Time: 1:00 to 5:00 PM (EDT)

Organizer: James Laverty

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.

CANCELLED W35: Moving Towards Accessibility in Physics Education with Universal Design for Learning

DATES: July 10, 2020 from 1:00 PM to 3:00 PM (EST) and July 17 from 1:00 PM to 3:00 PM (EST)

(This is a two day workshop)

Organizer: Jacquelyn J. Chini /Co-Organizers: Erin Scanlon and 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. The activities for this workshop will be spread across two days, allowing participants time to think more deeply aboutA the topics before practice applying them on the second day. In Day 1, participants will have the opportunity to: 1) reflect on the impact of ableism on physics culture; 2) reflect on their role in designing instruction that supports variation in students' needs abilities and interests; and 3) practice applying the guidelines to identify barriers in the learning environment and to design options and supports in sample written curricula and instructional scenarios. On the second day, participants will be invited to reflect on their own written curricula and/or classroom practices and design UDL-aligned strategies to implement. Participants will be offered access to a set of online resources and be invited to contribute to the resources for continuing to plan and implement strategies to make their instruction more accessible. Since the facilitators' experience is limited to postsecondary settings, this workshop will be appropriate for college/university instructors and curriculum developers. High school teachers and students are welcome to attend. Workshop content will incorporate views of students with disabilities about student-centered active learning STEM courses

Workshops, Saturday, July 11

W01: Learn Physics While Practicing Science: Introduction to ISLE

Date/Time: July 11, 2020 from 9:00 AM to 11:00 AM and July 12, 2020 from 9:00 AM to 1:00 PM (EST)

(This is a two-day workshop)

Organizer: David Brookes/Co-Organizers: Eugenia Etkina, Yuhfen Lin, Gorazd Planinsic, and Yuehai Yang

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 video experiments and activities for use in the classroom, laboratories, and homework; (c) a set of innovative labs in which students design their own experiments. 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 preserving the spirit of ISLE in an online environment.

W03: Introduction to PC Board Design and Manufacturing

DATE: Saturday, July 10 Time: 1:00 PM to 5:00 PM (EST)

Organizer: Paul Noel/Co-Organizer: Stephen Irons

Electronic devices can serve many useful purposes within a physics class or lab. They can be used for demonstrations, as part of a laboratory experiment, or serve as a student project. While electronic devices can be assembled on a solderless breadboard or soldered using generic perf board, it is surprisingly easy, and frequently the most inexpensive option to create a more permanent and electrically robust device by designing and ordering a custom printed circuit board (PCB). In this workshop you will learn how to design and manufacture a PCB for instructional uses. We will discuss and use several design options, including the free software EagleCAD and KiCad. Participants will be guided in how to create a schematic, select components, arrange the parts on a circuit board, and route the circuit. We will guide the participant through this process from beginning to end. They will also learn how to create the set of PCB manufacturing files (Gerber files), and the factors one should consider in choosing the particular manufacturer.

W06: PIRA Lecture Demonstrations I & II Condensed

DATE: Saturday, July 10 Time: 8:00 AM to Noon (EST)

Organizer: Dale Stille/Co-Organizer: Sam Sampere

During this ½ 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.

W43: Interactive Lecture Demonstrations (ILDs) and RealTimer Physics (RTP) Adapted for Active Distance Learning

Saturday, July 10 Time: 1:00 PM to 3:00 PM (EST)

Organizer: David Sokoloff/Co-Organizer: Ronald Thornton

With the need for distance learning materials thrust upon us alarmingly and suddenly, it is not unreasonable that many have fallen back on passive presentation of lectures and black/whiteboard notes using some mode of video conferencing. But is it possible to maintain some element of active learning for our introductory physics students? My colleagues and I have attempted to adapt both Interactive Lecture Demonstrations (ILDs) and RealTime Physics (RTP) for use in distance learning. We've used the wealth of multimedia materials currently available (videos, simulations, photos, computer-based laboratory graphs, etc.) to adapt ILDs (1), (2), (3) to a form that can be used by students at home (4). While recognizing that small-group discussions--and sharing in any way--may be difficult for most faculty to implement, these Home Adapted ILDs retain predictions as an essential element in engaging students in the learning process. For introductory lab activities, we have adapted RTP Mechanics (5) for use at home with the IOLab--an inexpensive, computer-based laboratory device (6). In this workshop, we will first review the design features of ILDs and RTP. Then we will work with some examples of Home Adapted ILDs. We will also explore the distance learning RTP labs for IOlab and discuss implementation issues.

Workshops, Friday, July 17

W37: Using RTOP to Improve Physics and Physical Science Teaching

DATE: Friday, July 17 Time: 1:00 PM to 5:00 PM (EST)

Organizer: Kathleen Falconer/Co-Organizer: Daniel MacIsaac

The Reformed Teaching Observation Protocol (RTOP) is a 25-item rubric that provides a percentile measure of the degree and type of student-centered, constructivist, inquiry-based, engagement in an instructional situation. RTOP scores correlate very highly with student conceptual gains. In this workshop, we will score video vignettes of teaching to learn how to use RTOP for guiding personal reflection and improvement and change of our own teaching; for mentoring peers, novice teachers and student teachers; and to establish a vocabulary for discussing reformed teaching practices.

W38: World Wide Data Day

DATE: Friday, July 17 Time: 1:00 to 5:00 PM (EST)

Organizer: Shane Wood/Co-Organizer: Kenneth Cecire

If you have computers and internet in your school, you can bring data from the Large Hadron Collider at CERN to your classroom. World Wide Data Day (W2D2) is an annual activity in which teachers and students do an analysis of muon tracks in LHC that is designed to be done in 2 class periods with or without outside assistance. On the day itself, classes at schools all over the world have video conferences with particle physicists to discuss the results. Learn how to implement the W2D2 measurements in your classroom and get your school involved.

W15: Get the Facts Out: Changing the Conversation Around Physics Teachers Recruitment

Date: July 17, 2020 Time: 1:00 PM to 5:00 PM (EST)

Organizer: Drew Isola /Co-Organizer: Wendy Adams

In this workshop we will share strategies and resources for recruiting students into physics, chemistry, math and general science teaching careers. The strategies include recommendations for sharing facts about teaching, how to talk to students, listing of venues for reaching students, updated recommendations and resources for sharing the facts virtually. The online resources provided include student presentations, posters, brochures, program flyer templates and presentations for faculty and staff who advise students. All materials are professional quality, research-based and have been extensively user-tested. These materials have been developed as part of Get the Facts Out, an NSF funded project for changing the conversation around STEM teaching recruitment. The project is a partnership between the American Physical Society, American Chemical Society, the Association of Mathematics Teacher Educators, and AAPT led by the Colorado School of Mines. This workshop is fully funded by NSF #1821710 & 1821462. Participants who complete this workshop can be reimbursed for their workshop registration fee.

W27: Machine Learning in PER

Date: July 17, 2020 Time: 1:00 PM to 5:00 PM (EST)

Organizer: Rachel Henderson /Co-Organizers: Nicholas Young and 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 have a laptop with Anaconda Python 3.x installed.

Workshops, Friday, July 24

W18: Introducing Students and Testing Hypotheses via Abstract Games

Date: July 24 Time: 10:00 AM to 2:00 PM (EDT)

Organizer: David Maloney

In this workshop participants will explore two activities using abstract strategy games that introduce students to the scientifically important processes of formulating and testing hypotheses. Since almost all students have experience playing games this approach to having students engage in these reasoning processes is more "user-friendly" than having them engage with physics content. In addition using abstract strategy games allows for comparisons in how the processes work in different knowledge domains. These activities also help students become comfortable actively working in groups for interactive engagement courses. After exploring both activities the workshop will close with a general discussion of how such activities and the nature of science might fit into various courses. Participants will be given an extended set of materials for each of the two activities.

W23: Activities from the Living Physics Portal

Date: July 24, 2020 Time: 1:00 PM to 5:00 PM (EDT)

Organizer: Nancy Beverly /Co-Organizer: Sam McKagan

Join other highly engaged physics instructors in exploring, re-thinking and adapting introductory physics activities and assignments for health science and life science students to emphasize interdisciplinary connections. Participants will be exposed to practical changes they can implement at their home institutions that put students' experiences at the center of classroom interactions. Participants will join a growing network of physics instructors who share curricular materials and troubleshoot instructional challenges through the Living Physics Portal. Participants will use the Portal to share resources and collaborate with other physics educators. Instructors, lab managers, & community college faculty and those with varying degrees of familiarity with physics for life scientists or active learning are welcome! The goals of the workshop are to enable and excite participants to (a) make curricular or lab changes, (b) focus on students' experiences and learning, and (c) make physics personally meaningful and coherent with students' other STEM knowledge.

W26: Coding Integration in High School Physics and Physical Science

Date: July 24, 2020 Time: 1:00 PM to 5:00 PM (EDT)

Organizer: Chris Orban/Co-Organizer: 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 2017 AIP Meggers Project Award.

Workshops, Saturday, July 25 Time (EST) Organizer(s)

W12: Technical Competencies in Laboratory Courses

Dates: July 25 and July 26, 2020 Time: 10:00 AM to Noon (EST) on both days

(This is a two day workshop)

Organizer: Randy Tagg/Co-Organizers: Kris Bunker and Devin Pace

How can physics students develop a repertoire of practical knowledge useful in research and industrial jobs in a way that is enriched by physics concepts and modeling? First, we will delineate types, topics, and levels of technical competency in design and instrumentation that students could achieve. Then explicit examples of apparatus and procedures will show, using a common Jupyter-notebook based instructional format, how physics students develop skills and confidence in such technical competencies. Some of the apparatus will be illustrated online with photos and then sample data sets will be provided for further analysis: for example, a wire pulling device generates stress-versus-strain data to teach students about material mechanical properties. Other apparatus would show how to use python and the "Firmata" protocol to interact with Arduinos for data acquisition and control. A final portion of the workshop will be an open discussion in which we imagine real-world contexts in which such competencies are needed and then prioritize the specific technical competencies that physics students might aim to acquire.

W21: Using Astronomy Demonstration Videos

Date: July 25, 2020 Time: 9:00 AM to 1:00 PM (EST)

Organizer: Kevin Lee/Co-Organizer: 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. Participants will only pay $25 to attended this workshop, since the rest will be covered by a grant. This project is funded by NSF award #1245679.

W33: Teaching Physics towards Social Justice

Date: July 25, 2020 Time: 11:00 AM to 1:00 PM (EST)

Organizer: Moses Rifkin/Co-Organizers: Abigail Daane, Danny Doucette, Andrew Morrison, and Johan Tabora

Motivated by our shared desire to address under-representation in physics and support systematically marginalized 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.

W39: Intermediate and Advanced Laboratories

Date: July 25, 2020 Time: 1:00 PM to 5:00 PM (EST)

Organizer: Jeremiah Williams

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.

Workshops, Sunday, July 26

W36: Work and Energy Workshops

Date: July 26, 2020 Time: 1:00 PM to 5:00 PM (EST)

Organizer: Gay Stewart

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.

W29: Fillip The Physics Classroom! A How to Guide to Making your own Flipped Instructional Videos

Date: July 26, 2020 Time: 10:00 AM to 2:00 PM (EST)

Organizer: Vanessa Wentzloff

Ever wondered what it would be like to try to flip the instruction in your classroom? This workshop will explore the benefits and approaches to flipping your physics instruction AND will help you make your first flipping instructional videos. Come ready with a lesson topic and your best video persona and leave with a new skill and a starter video.

Workshops, Friday, July 31

W44: STEP UP

Date: July 31. 2020 (EDT)Time : 12:00 PM to 4:00 PM

Organizer: Nicole Harvey/Co-organizers: Brian Kays, Mark Wadness

High school physics teachers, in particular, have been found to be critical to inspiring young women who pursue undergraduate physics. 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 for 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 only one-third of high school physics teachers was able to recruit an interested young woman to a physics undergraduate program, gender imbalance upon enrollment would be offset. Undergraduate faculty have a special role to welcome and retain these young women. Whoever you might be, be a part of the change! (This workshop is fully funded by NSF #1720810. Participants who complete the workshop may seek full reimbursement of their workshop registration fee.)

Session: SPS Undergraduate Poster Session **Sunday, July 19, 2:30–3:30 p.m**

Sponsor: SPS/AAPT **Presider:** *Brad Conrad*

SPS: 2:30-3:30 p.m. A Novel Method of Measuring Airplane Thrust

Poster – Margaret H. Capalbo, Lewis University, Plainfield, IL 60586-7399*

Airplane thrust is currently measured using a complex equation that requires many thermodynamic measurements, such as air pressures, mass flow rates, and air velocities. To provide a new, more direct method of thrust measurement and a cross check for pilots, a device that is attached to the engine mounts that can measure force or a compressive load is needed. Annular piezoelectric washers have been studied to understand their properties, such as resolution and linearity. Sample piezoelectric sensors were calibrated on an in-lab test stand according to various torques Calibrated piezoelectric sensors were installed and tested on a PT6 engine test stand within the aviation department and showed a correlation between frequency and thrust measurement.

*Sponsored by: Dr. Ryan Hooper

SPS: 2:30-3:30 p.m. A Tale of Two Sections: Work, Energy, and Different Systems

Poster – Claire Allen, Kearney, MO 64060-7449

Brant E. Hinrichs, Department of Physics, Drury University

It is well known that students struggle with thinking about work and energy in the context of different system choices. University Modeling Instruction (UMI) tries to address this by using the system schema representation (SS) and energy pie charts (EPC) An SS is a diagram that helps students explicitly identify which objects are inside their system and which are not. EPC are diagrams that explicitly help students track the relative amounts of different forms of energy inside their system, how they change over time, and whether energy is entering or leaving the system. We report the results of an exam problem based on the literature for a first semester algebra-based introductory physics class. There were two sections, with very similar student populations, taught by the same instructor, using the same materials, yet one section was much more successful than the other. We compare these results to results from the literature.

SPS: 2:30-3:30 p.m. Assessing Shifts in Lab Assistant Attitudes

Poster – Jessica Martin, BYU, Provo, UT 84606*

Nathan Powers, BYU

Many of the physics lab courses at BYU have shifted their focus from highly structured, concept-reinforcement to a more open-ended project-based approach to exploration and investigation. This new approach to labs requires a change in the role of lab assistants, which is often at odds with what new lab assistants expect their role to be. Even after training, they can revert back to concept-focused behavior. We investigate how a new training process involving targeted training meetings, peer observations assessments, self-evaluations, and reflection tools, impacts the lab assistant perception attitudes in three main areas--leadership, knowledge construction, and technical skills. We use a codified system to analyze responses from the lab assistants to determine if their attitudes have solidified.

*Sponsored by: Nathan Powers

SPS: 2:30-3:30 p.m. Conceptions of Community Among Physics Majors and Learning Assistants

Poster – Jason Taylor Starita, George Washington University, Washington, DC*

Gary White, George Washington University

In this study, the experiences of students in the Physics LA program are compared to the experiences of those who study physics but have not participated in the program at the George Washington University. We are interested in how participation in the LA program influences physics identity and how the students conceptualize the physics community. We analyze 15 interviews conducted by students belonging to three different populations (five from each population): LAs who are not physics majors, LAs who are physics majors, and physics majors who are not LAs. By analyzing the coded language used by interviewees, we hope to better understand how participation in the LA program effects beliefs of community. The results of this study will be used to identify critical elements of LA program structure that influence physics identity and inform how beliefs of community influences both LAs and physics majors in their physics identity development

*Sponsored by Gary White

SPS: 2:30-3:30 p.m. Dynamic Analysis of the Falling Process of Disc Tower

Poster – Shidong Zhu, JiuLongHu campus, Southeast University, Nanjing Nanjing, Jiangning 211102

Identical discs are stacked one on top of another to form a freestanding tower, if the bottom one gets pulled out, the upper ones will stagger a distance from each other. From the slow motion it can be found that the disks will not stagger before falling on the ground. The reason for the stagger is the tower's rotation around the center of mass. And we work out the condition that the tower does not collapse in the first order approximation. Our experimental results coincide the graph very well.

SPS: 2:30-3:30 p.m. Electrostatics and Riemann Surfaces

Poster – Spencer Tamagni, University of Central Florida

Costas Efthimiou, University of Central Florida

Using techniques from geometry and complex analysis in their simplest form, we present a derivation of electric fields on surfaces with non-trivial topology. A byproduct of this analysis is an intuitive visualization of elliptic functions when their argument is complex-valued. The underlying connections between these techniques and the theory of Riemann surfaces are also explained.

SPS: 2:30-3:30 p.m. How Force and Energy Notation Affects the Way Students Say it

Poster – Dayna Swanson, Drury University

Brant Hinrichs, Drury University

To facilitate learning in the physics classroom, University Modeling Instruction uses a consistent symbol pattern within each concept. For example, the symbol is E_k for kinetic energy, E_{int} for internal energy, etc. and $\vec{F}^{g}_{E\rightarrow B}$ for gravitational force by Earth on Ball, $\vec{F}^{c}_{R\rightarrow S}$ for contact force by Rope on Sled, etc. For energy, we find that although the subscript appears on the right-hand side, no students ever say "energy kinetic" or "energy internal". They say what we expect – "kinetic energy" and "internal energy". In contrast, for force, with the super-script on the right-hand side, 40% of the time students say "force gravity" for $\vec{F}^{g}_{E\rightarrow B}$ and "force contact" for $\vec{F}^{c}_{R\rightarrow S}$ while with the super-script on the left-hand side (i.e. ${}^{g}\vec{F}_{E\rightarrow B}$ and ${}^{c}\vec{F}_{R\rightarrow S}$), use of "force gravity" and "force contact" drops to less than 2%. We discuss some initial ideas for why students might say the symbols differently.

SPS: 2:30-3:30 p.m. iTEBD Method for Ground State Properties Computation

Poster – Zhiyao Ning, SUN YAT-SEN UNIVERSITY Guangdong 510275 China

Daoxin Yao, Guangyi Liang, SUN YAT-SEN UNIVERSITY*

The study on physical quantities in ground state quantum multi-body system can get not only the statics properties but also the dynamical properties of the system. We use infinite time-evolving block decimation (iTEBD) to compute the n particles 1-D Ising spin chain with periodic boundary condition and get the normalization ground state in expression of matrix product state (MPS). After contract the MPS we get the reduced density matrix of the ground state system, applying physical operators on which we can get the physical quantities we need. The ground state energy is compared with the exact diagonalization result and show pinpoint accuracy. For further research, we are embarking on improving the algorithm to computing the imaginary time correlation function of the system.
Sponsored by Zhencheng Huang

SPS: 2:30-3:30 p.m. On Chemical Potential of Phonons in Einstein Solid Model

Poster – Jixuan Hou JiuLongHu,Southeast University, Nanjing Nanjing, Jiangning

Thermodynamic quantities of the Einstein solid model are studied via the microcanonical approach. We point out that the number of phonos in Einstein solid model cannot be defined independently and thus the chemical potential of phonos cannot be defined in the microcanonical ensemble. The chemical potential of phonos can be calculated only if the number of phonons can fluctuate. And we prove that the chemical potential of phonos in Einstein solid model strictly equals to zero in other ensembles.

SPS: 2:30-3:30 p.m. Precise Analysis of a Particle's Motion on an Elliptical Track

Poster – Kai Yan, Southeast University, China Xuyi County, Huai'an, Xuyi 211700 China

Particles' motion on a circular track is commonly discussed in elementary Physics. This paper extends the precise analysis to the elliptical condition and friction is considered. The link between the velocity of a particle and its position on an elliptical track with friction is accurately established, essentially based on the transformation of angels through analytical geometry. After identifying conditions in which the particle won't fall, the whole process of the motion is depicted.

SPS: 2:30-3:30 p.m. Project-based Learning: Physics-I with MatLab

Poster – Yara Abazah, Bergen Community College, Paramus, NJ 07652

Leyki Reynoso, Neel Haldolaarachchige, Bergen Community College

Kalani Hettiarachchilage, Seton Hall University

Kinematic concepts are simulated with MatLab. Project-based assignments are done as the class progresses throughout the semester. Assignment per chapter is given with a few selected and challenging questions. Questions are first solved analytically then computationally simulated to get the behavior of practically relevant variables. Many body problems with kinematics, dynamics, energy conservation, rotational motion, gravitation, and simple-harmonic-motion have been solved. The main focus is given to simulate practically relevant problems, in which some problems are not possible to solve analytically. Solving selected problems analytically helped students to get deeper understating of the concept whereas simulating analytically-difficult problems with MatLab helped them to learn and use scientific programming for problem-solving and get a better understanding of the concepts. At the end of the semester group projects are done to simulate selected applications. The project results are presented and discussed in the class.

SPS: 2:30-3:30 p.m. Project-based Learning: Designing New Lab Setup

Poster – Lucus Cordova, Bergen Community College, Paramus, NJ 07652

Avee Patel Bergen, Neel Haldolaarachchige, Community College

Kalani Hettiarachchilage Seton Hall University

Home built, easy use and low-cost freefall apparatus is reported. It has two important sections: photogate timer with two photogates and electromagnet with clicker switch. We select a very small electromagnet that works with 12 V DC and can hold a maximum weight of 20 pounds. All the clamps are designed and 3D printed. There are two different types of clamps; one for photogate and the other for cylindrical shape electromagnet. Assembly of the complete system will take only a few minutes and in general classroom, every two or four-member student group can do the experiment independently. A small electromagnet is set up at the top of the regular lab stand with a metal rod. Two photogates are set below the lab stand. Any object with a metal tip can be attached to the electromagnet. Times between photogates are taken with increasing distance between photogates. The gravitational constant is confirmed within one percent error.

SPS: 2:30-3:30 p.m. Silicon Nitride Metalenses for Polarization-depended and Multi-wavelength Imaging

Poster – Jianwei Qin Sun Yat-sen University, Guangdong 510275 China

As one of the emerging semiconductor materials, SiN's excellent dielectric properties, high material stability, and dispersion controllability make it widely used in both linear and nonlinear all-optical integrated devices. Here, we designed a single-layer metasurface using silicon nitride posts and realized high-transmittance metalens. Existing solutions for multi-wavelength meta-optics inevitably increase the device thickness and system complexity, whereas the refractive and diffractive counterparts also limit the polarization-sensitive lenses with a small numerical aperture(NA). By creating a single-layer array of SiN elliptical posts with different sizes and orientations, we introduced a modulation scheme to design multi-wavelength metalens which can work on different orthogonal polarizations. Our approach realized a polarization-depended achromatic metalens with large NA.

SPS: 2:30-3:30 p.m. Thematic Analysis of Student Manipulations of the PhET Simulation "Fluid Pressure and Flow"

Poster – Jeffrey Rosauer, Illinois State University, Deer Park, IL 60010

Andrew Princer, Justin Szela, Grant Kaufman, Rebecca Rosenblatt, Illinois State University

Student difficulties with fluid statics and dynamics concepts often persist with conventional instruction. A curriculum was developed using a simulation to improve student understanding of fluid statics and dynamics taught in an introductory algebra-based physics courses for life science students. Screen capture videos were made of students completing a 20-minute guided inquiry tutorial that used the PhET simulation "Fluid Pressure and Flow". These videos were studied using qualitative thematic analysis to identify common actions and patterns of actions as students worked through the curriculum. Patterns observed from this analysis are compared and contrasted with the patterns made by experts working with the simulation. Additionally, pre- and post-activity assessments of student knowledge of fluid speed and pressure in pipes were made. These data were examined to establish what connections exist between actions made while working with the simulation and changes in students conceptual understanding of fluids.

SPS: 2:30-3:30 p.m. Trajectory of Flying Card

Poster – Yanbo Wang, China, Jilin, Changchun Changchun, Nanguan 130000 China

Shidong Zhu, Donghao Wu

A card with an initial velocity and initial angular velocity can fly in the air for a while, and finally it will fall on the ground. During the flying process, the air friction and viscous resistance act on the card continuously so that the kinestate of the card changes all the time. This makes the trajectory of a flying card look like a question mark. We first use kinetic equation to analyze the trajectory and make an assumption. Then, we use camera to collect necessary statistics of a flying card to explore the real trajectory and check the assumption we have put forward before. Our experimental and theoretical results match well.

All invited and contributed sessions, as well as poster presentations, have been pre-recorded and will be released for viewing on July 16. You are encouraged to view the recordings ahead of time, submit your questions, and tune in for the live Q&A with the authors at the times listed below. The dates and times on this agenda are the scheduled Q&A for each session or poster. **Times are EDT**

Session PAR-A.01: AAPT Speakers Bureau: Purpose and Samples

Sunday, July 19, 11:30 a.m.–12:30 p.m.

Sponsor: Committee on the Interests of Senior Physicists

This session will acquaint attendees with and encourage their use of the AAPT Speakers' Bureau. It will begin with a description of the history and purpose of the Speakers' Bureau, including information about how to request a speaker and how to register as a speaker. It will conclude with brief presentations by several of the available speakers.

PAR-A.01: 11:30 a.m.-12:30 p.m. AAPT Speakers Bureau: Mysteries of Quantum Physics

Invited – Chandralekha Singh, University of Pittsburgh, Pittsburgh, PA 15260

The AAPT Speakers Bureau provides AAPT members with an opportunity to share their passion, excitement and expertise in physics with the public as well as students at all levels. I have always enjoyed sharing my passion for quantum physics with the public and K-16 students. Quantum mechanics is a powerful and mysterious theory. It is our best theory for explaining everything we understand about the properties of matter and the world around us. This understanding has led to incredible transformation of science and technology in the last century. However, even Einstein was disturbed by some of its predictions. We are still doing experiments to understand the most unsettling predictions and foundations of quantum physics. At the same time, researchers are using the most bizarre aspects of quantum theory to create new technologies like quantum computers. It is never too early to learn about the fascinating mysteries of quantum physics.

PAR-A.01: 11:30 a.m.-12:30 p.m. Benefits of AAPT to High School Physics Teachers

Invited – Jan Mader, Great Falls High School, Great Falls, MT 59404

As a high school teacher and E-mentor I have found a wealth of information within the AAPT organization to not only assist with my own instruction but to provide support for new teachers in the field. Everything from adopt a physicist to digi-kits is at my finger tips. As a physics teaching association I believe many members do not realize the breadth of resources available and much of the resources are underused.

SUNDAY

PAR-A.01: 11:30 a.m.-12:30 p.m. Computational Modeling in an Introductory Physics Course

Invited – Thomas O'Kuma, Lee College, Baytown, TX 77522-0818

You and/or your department are interested in introducing computational modeling into your introductory physics courses, but want some concrete ideas of how to accomplish this. You want it to be student friendly; i.e., not requiring much prior student programming experience. You want it to be instructor friendly; i.e., not requiring huge time investment for the faculty to implement. You want it to be affordable; i.e., not requiring a huge investment by the department, faculty or student. This presentation will illustrate a way to accomplish introducing computational modeling into introductory physics courses.

PAR-A.01: 11:30 a.m.-12:30 p.m. Contributing to the AAPT Speakers Bureau: Students as Collaborators in Creating Effective, Inclusive Learning Spaces

Invited – Mel Sabella, Chicago State University, Chicago, IL 60628

Jamia Whitehorn, Ember Smith, Gregory Curry, Andrea G. Van Duzor, Chicago State University

The AAPT Speakers Bureau can be a powerful tool to share the expertise of AAPT members and disseminate the diverse work we do to support physics education at all levels throughout the world. The work of my group, at Chicago State University, focuses on supporting students underrepresented in physics by creating opportunities for faculty to collaborate with students on education reform efforts. Much of this work leverages the Learning Assistant Model, input from students, and input from undergraduate education researchers. This student expertise can create effective, inclusive learning environments as well as shifts in who has power in the classroom and who has power in how our learning environments are structured. These are exciting spaces to work in for both faculty and students who all play a role in how we think about physics teaching and learning.

Supported by the Department of Education, the National Science Foundation (DUE# 1524829), and the Illinois Space Grant Consortium

PAR-A.01: 11:30 a.m.-12:30 p.m. Lab Equipment for EVERYONE in Alabama!

Invited – Tommi Holsenbeck, Alabama Science in Motion/ASU, Hardaway, AL 36039

Imagine if every public high school science department had thousands of dollars' worth of high-tech equipment available to educate their students…with Alabama Science in Motion they have access to that and more! 33 classroom teachers (specialists in Physics, Biology or Chemistry) at 11 universities across the state deliver over $11 million work of labs, demos, equipment and more direct to science classrooms. Through workshops, co-teaching, and online methods ASIM works with teachers. This "share the wealth" model can be adopted in all states. Look at our website: www.cws.auburn.edu/asim to see the lessons using learning cycles, white boarding, PER, formative assessment, teacher sharing and more. Many additions to the physics program came from the MSP APEX Grant at Alabama A&M, in partnership with AAPT. ASIM enables physics teachers to acquire a deeper knowledge of physics content and employ more effective pedagogical strategies based on physics education research, enabling students to achieve higher gains.

PAR-A.01: 11:30 a.m.-12:30 p.m. Motivation for the Speakers Bureau

Invited – Gordon P. Ramsey, Loyola University Chicago

Many speakers' bureaus exist to provide lists of potential speakers for important events. Scientific bureaus tend to provide lists of speakers with specific expertise in science related topics. The AAPT Speakers Bureau was established early last decade to provide AAPT members and sections with information on available speakers for physics related events. The list can be used for local or national meetings and contain a wide variety topics related to physics and physics education. It is searchable, by geography (sections), topics or speakers names. I will give a small sample of two popular talks that I have given in many locations as an example of what the speakers' bureau can provide. These are "Physics of Music" and "Physics of Cats". The AAPT Speakers' Bureau can be found at: https://aapt.org/Resources/speakers_bureau-landing.cfm.

PAR-A.01: 11:30 a.m.-12:30 p.m. The Future of Optics is Programmable

Invited – Gabriel C. Spalding, Illinois Wesleyan University, Bloomington, IL 61702

We teach Optics by leveraging a coherent series of hands-on laboratory engagements that connect well with classroom discussion of mathematical modeling. These labs directly explore mathematical models contained in Optics texts, commonly utilizing liquid crystal Spatial Light Modulators (SLMs), which allow simple and direct programmatic control of phase, amplitude, or polarization across the field of a beam of light. As added bonus, their use avoids the excessive burdens associated with manual alignment and re-alignment (and re-alignment and...) that would be required for systematic studies based on traditional (fixed) optical components. Again, SLMs allow direct control of amplitude and phase modulation of beams, which is useful for teaching Fresnel Diffraction, Fraunhofer Diffraction, and Fourier Optics, as well as spatial filtering, computer-generated Holograms, Aberration Correction, Laser Modes, and much, much more (e.g., encoding information, the linear momentum, spin angular momentum, and orbital angular momentum of light beams).

PAR-A.01: 11:30 a.m.-12:30 p.m. Using Spandex to Teach Physics

Invited – Gary D. White, George Washington University, Physics Dept., Washington, DC 20052

A sheet of spandex is a terrific accessory for any physics classroom, useful for a wide variety of activities from exploring solar system origin and structure to modeling tidal effects to visualizing electrostatic potential wells to making adjustable slingshots. I will demonstrate how I use spandex both in my own classrooms and in presentations to the general public, and provide some background about the physics of stretched spandex.

Session PAR-A.02: Best Practices in Educational Technology

Sunday, July 19, 11:30 a.m.–12:30 p.m.

Sponsor: Committee on Educational Technologies

PAR-A.02: 11:30 a.m.-12:30 p.m. A Computational CURE: Canopy Waves, Colliding Galaxies, and Traveling Salestronauts

Invited – Nicholas Nelson, California State University, Chico, Chico, CA 95969-0202

Dillon Anderson, Sean Dillon, Harman Khinda, Cynthia Olvera Perez, Eric N. Strauss, Lennard Vanderspek, Blake Buckner, Bjorn Larsen, and Joshua Meadows, California State University, Chico

Involvement in undergraduate research has been shown to have positive effects on physics students, including improved conceptual and technical understanding, increased interest in graduate study, enhanced motivation for future coursework, and better scientific communication skills. Summer research programs, however, have not kept pace with the roughly tripling in the number of physics majors over the past 20 years. An alternative model is that of Course-based Undergraduate Research Experiences (CUREs) in which students gain research experience through a course. Here we present an example of a CURE in computational physics which produced three research projects: first, computational fluid dynamics model of so-called canopy waves, which have been observed in wind blowing through orchards; second, updating a classic result from astrophysics that explains the morphology of colliding galaxies; third, a futuristic update on the traveling salesman problem where our salesman travels through the solar system, which we term the traveling salestronaut.

PAR-A.02: 11:30 a.m.-12:30 p.m. Integrating Computation in Introductory Physics Labs

Invited – Steven Wolf, East Carolina University, Department of Physics, Greenville, NC 27858-4353

At East Carolina University, we have been transforming our Introductory Lab Curriculum to privilege authentic science practices as a part of our XLABs (Cross-Disciplinary Lab Transformation) project (NSF-IUSE: #1725655). One of the science practices identified by the NGSS is analyzing and interpreting data. This practice is executed in computational environments in all modern scientific and engineering settings. I will discuss how we are integrating computation in our Introductory Physics labs, focusing on the environments that we are using and the ways that we are supporting student computational skill development.

PAR-A.02: 11:30 a.m.-12:30 p.m. Physicality and Making in a Computational Physics Class

Invited – Timothy Atherton, Tufts University, Medford, MA 02155-5555

Brian Gravel, Ezra Gouvea, Tufts University

Computation is inextricably intertwined with virtually every aspect of contemporary physics research practice including design of experiments, creation of theory, simulations as well as collection, analysis and visualization of data. In contrast, computational activities in physics classrooms have tended to focus on coding, problem-solving and simulation. To bridge this gap between pedagogy and practice, we have developed a series of making activities whereby students create physical artifacts from low-cost materials, collect quantitative data describing their motion, build models to predict their behavior and reconcile experiment and theory. Results from our first two trials in a group and project-based Computational Physics class will be presented, showing how this approach enables students to engage in disciplinary practice. Design and implementation advice for instructors interested in adopting similar techniques will be provided. Organized by Kelly Roos

Session PAR-A.03: Best Practices for Developing Scientific Thinking, Reasoning, and Decision-Making Abilities

Sunday, July 19, 11:30–12:30 p.m. Sponsor: Laboratories Committee Co-Sponsor: Committee on Physics in Two-Year Colleges

PAR-A.03: 11:30 a.m.-12:30 p.m. A Modeling Framework of Scientific Thinking and Reasoning*

Invited – Lei Bao, The Ohio State University, Columbus, OH 43210-1117

Kathleen Koenig, University of Cincinnati

An essential element of STEM education of the 21st century is the development of scientific thinking, reasoning, and decision-making abilities. In the current literature, there exist multiple schools of thought on various aspects of scientific thinking and reasoning; however, the research community has yet to reach a consensus on the definition, theoretical foundation, and assessment scales of scientific reasoning. This presentation will introduce a comprehensive modeling framework as well as a new assessment instrument on scientific reasoning, which are developed with an emphasis on the process of theory-evidence coordination (TEC). Future work and possible collaborations will also be discussed.

*Supported in part by the NSF IUSE-1431908 and IUSE-1712238

PAR-A.03: 11:30 a.m.-12:30 p.m. Junior Physics Laboratory: Scientific Reasoning, Communication, and Decision Making

Contributed – Karen A. Williams, East Central University, Ada, OK 74820

Ask your colleagues how they learned to do research. Most of us learned how to do research by reading publications our advisor told us to read and discussing the research with the research group or the group leader. We basically learned by doing something similar to that which has been already done and failing. In the failing, we modified some part of what we were doing and tried again. In this presentation I will present what my students do in Junior Lab to learn about designing a lab, communicating the results, and decision making in the process. I will also share my evaluation of their actions and reflect upon this process.

PAR-A.03: 11:30 a.m.-12:30 p.m. The Role of Structure and Confirmation in Developing Scientific Thinking, Reasoning, and Decision-Making Abilities

Invited – Natasha Holmes, Cornell, Ithaca, NY14850

Many instructors are working to transform their traditional labs to better develop scientific thinking, reasoning, and decision-making abilities. Traditional labs, defined as being highly structured (students follow a predetermined protocol) and confirmatory (that protocol is supposed to demonstrate a predetermined physics principle), have long been criticized for not engaging students with authentic experimentation. As defined, students have very little opportunity or incentive to make decisions or think critically about the experiments or results. In response, we often default to reducing structure and affording more agency so students can practice making experimentation decisions. Research is suggesting that this response may be overly simplistic. In this talk, I'll discuss the nuances of structure and agency in teaching scientific decision-making and argue that the role of confirmation may actually be the more critical issue than structure.

PAR-A.03: 11:30 a.m.-12:30 p.m. Transforming Lab Instruction to Promote Essential Scientific Reasoning Abilities*

Invited – Kathleen M. Koenig, University of Cincinnati, Cincinnati, OH 45221

Lei Bao, The Ohio State University

Addressing complex societal problems requires STEM workers with expertise such that they are able to recognize, understand, and effectively reason out solutions using principles of their disciplines. This need emphasizes the importance of skills-based learning. This presentation will provide details about the development of an introductory physics lab curriculum, which was designed around the theory-evidence coordination (TEC) framework to advance select reasoning skills through scaffolded lab activities. Best practices for using the TEC framework to modify existing curriculum will be provided along with how one might assess subsequent impact on student development of scientific reasoning. We will also discuss our interest in pilot sites for our curriculum.

*Partially supported by the NSF IUSE 1431908

PAR-A.03: 11:30 a.m.-12:30 p.m. Uncovering and Using Internet Videos to Develop Physics Sense-making

Contributed – Shen Yong Ho, Nanyang Technological University, Singapore 21, Nanyang Link Singapore,

Other than traditional lecture demonstrations, there are also many everyday life events, such as car crashes and lightning strikes that also aptly demonstrate concepts in Physics but cannot be easily recreated in class. Today, many of these events are captured on video and are easily available on the internet. To facilitate teachers to find what they need, we classify online videos useful for Physics teaching into six broad categories. Not only are these carefully selected videos useful for illustrating the relevance of Physics to daily life, they also allow students to practice making sense of their observations and identifying the underlying Physics principles at work. Sense-making is key to the learning of Science. We will discuss four key strategies for designing class activities to help students exercise sense-making of the underlying Physics in the videos.

Session PAR-A.04: PER: Assessment, Grading and Feedback

Sunday, July 19, 11:30 a.m.–12:30 p.m.

Sponsor: AAPT

PAR-A.04: 11:30 a.m.-12:30 p.m. Assessing Students in Planning Investigations

Contributed – Hien Khong, Kansas State University, Manhattan, KS 66502

James T. Laverty, Kansas State University

College courses are attempting to apply three-dimensional learning to both the instruction and assessment. This transformative way engages students in doing scientific practices and deepening disciplinary knowledge in physics. We used Evidence-Centered Design and the Three-Dimensional Learning Assessment Protocol to assess students' ability to engage in the scientific practice of Planning Investigations. We conducted a written exam and Think-Aloud interviews to collect data from physics students in introductory college course. We analyzed interviews using the lenses of planning theory and model-based reasoning in laboratory. The analysis helped us to identify the model of planning investigations process conducted by college students during assessment. Results from this analysis will help us interpret students' written work and support the development of assessment tasks in the future.

PAR-A.04: 11:30 a.m.-12:30 p.m. Development of an Instrument Designed to Measure Student Reasoning*

Contributed – Brianna Santangelo, North Dakota State University, Fargo, ND 58102-1352

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. As conceptual understanding is required to reason productively, it is challenging to design an assessment tool that solely focuses on student reasoning. To address this challenge, 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 between responses to screening and target questions is used to make inferences about students' reasoning skills. We will discuss pre- and post-test performance on these sequences of screening-target questions from algebra and calculus-based physics courses and the inferences that can be drawn about students' development of reasoning skills in the context of physics. Preliminary results indicate the instrument can measure changes in student reasoning skills and detect differences in students with different backgrounds.

*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

PAR-A.04: 11:30 a.m.-12:30 p.m. Development of an Instrument to Measure Student Assistants' PCK-Q

Contributed – Beth Thacker, Texas Tech University, Lubbock, TX 79409-1051

Jianlan Wang, Stephanie Hart, Kyle Wipfli, Texas Tech University

Student assistants (SA), including graduate and undergraduate teaching/learning assistants, are pivotal to non-traditional physics instruction in large classrooms. Despite the importance and necessity of SAs, little is known about SAs' pedagogical content knowledge (PCK) and its impact on students' learning. We are particularly interested in SA's PCK of questioning (PCK-Q) skills as that may be key to effective SA-student interaction. Our goal is to design and validate a written instrument to measure PCK-Q. Based on video analysis of SA-student interactions in an inquiry-based, introductory physics class, we are developing and validating open-ended questions for this instrument. The questions are tested on SAs, and their answers, in conjunction with analysis of their PCK-Q from video data, are used for question revision and instrument redesign. Once developed, we will use the instrument to study the impact of SAs' PCK-Q on college students' conceptual understanding of physics and critical thinking skills.

PAR-A.04: 11:30 a.m.-12:30 p.m. How Students Use Ungraded Exam Review Problems

Contributed – Michelle R. Tomasik, Cambridge, MA 02139

Darcy G. Gordon, MIT

We have a large introductory physics course for non-majors, comprised mainly of First Year Undergraduate students. We provide for them a number of multiple choice and formula response questions online to help them prepare for the exams. While we do have other graded components of the course online, this part is set to be ungraded and allows them to see the solutions after a single attempt. We use data collected on the online student responses to explore student study behavior. For example, we were curious to see how students used this online answer checker to help them study for exams - did they try until they got the answer themselves or did they simply put in a junk answer in order to be able to read the solution?

PAR-A.04: 11:30 a.m.-12:30 p.m. Initial Implementation of an Upper-Division Thermal Physics Assessment

Contributed – Katherine D. Rainey, University of Colorado Boulder, CO 80012

Michael Vignal, Bethany R. Wilcox, University of Colorado Boulder

Thermal physics encompasses thermodynamics and statistical mechanics content and is a core upper-division course requirement for most physics degrees. Thus, in order to improve student outcomes in these courses, it is important for both educators and researchers to have a validated method of evaluating student understanding of upper-division thermal physics content. For an assessment like this to be useful, it is crucial that the assessment tool can be both easily implemented and easily scored. In this presentation, we discuss a multiple response upper-division thermal physics assessment that was distributed in an online format in the Spring of 2020. The development of multiple choice and coupled, multiple response assessment items and initial implementation of these items, including validation, will be discussed.

PAR-A.04: 11:30 a.m.-12:30 p.m. Interview Study of Learning Goals in Computational Integrated Introductory Physics

Contributed – Justin Earl Deskins Gambrell, Drexel University, Philadelphia, PA

Eric Brewe, Drexel University

Computationally integrated physics classes lack assessment of the approaches to computation. The recent call for integration of computation within physics curricula should be supplemented with the appropriate assessment. We present analyses of an initial set of interviews geared toward determining the learning goals in computationally integrated introductory physics classes. These interviews are the first part of a larger study aimed at creating an assessment for computationally integrated physics classes. Interviewees were chosen based on our perception of their involvement in computation, introductory mechanics, and physics education research. Interviewees were either categorized in academia or industry and the interview protocol was adapted to both populations. Semi structured interviews were performed through recorded video calls which were transcribed. We used grounded theory to analyze the interviews. The analysis of these interviews is ongoing. Data collected from these interviews will be used to design a survey for further consensus of the learning goals.

PAR-A.04: 11:30 a.m.-12:30 p.m. Making Inferences About Students' Abilities in Using Math in Assessments

Contributed – Amali Priyanka Jambuge, Kansas State University, Manhattan, KS 66502

James T. Laverty, Kansas State University

Bringing Scientific Practices (SP), Core Ideas (CI), and Crosscutting Concepts (CC) (aka three-dimensional learning), into college courses raises the need for assessments that can elicit students' competencies in engaging in those dimensions. The Three-Dimensional Learning Assessment Protocol (3D-LAP) provides criteria for each SP, CI, and CC to characterize and develop assessment tasks to elicit evidence of students' engagement in each dimension. How can we make inferences about students' abilities to engage in SPs? We articulate a methodology to explore student abilities to intertwine the SP of Using Math with physics concepts at introductory level. We developed tasks that can elicit Using Math along with a CI (and CCs) and gave them to students in one-on-one, video-recorded, Think-Aloud interviews. In this talk, we explain this process of making inferences from students' work products. This work helps us extend this process to the rest of the SPs as a whole.

PAR-A.04: 11:30 a.m.-12:30 p.m. Student Perspective About the Impacts of Feedback

Contributed – Carissa Myers, Michigan State University, East Lansing, MI 48912-4934

Rachel Henderson, Daryl McPadden, Paul Irving, Michigan State University

Projects and Practices in Physics (P-Cubed) is a flipped, problem-based learning course for introductory, calculus-based mechanics. P-Cubed was designed using the communities of practice framework, with a principle learning goal to develop scientific practices. To promote students' development of practices, students spend their in-class time working in groups of 4 to 5 members to solve complex physics problems. Practice development is then facilitated through formative feedback and assessments aligned with growth in practice. Each student receives weekly, individualized feedback from their instructor (either a faculty member, teaching assistant or learning assistant) as a practice-based assessment. The feedback focuses on helping students improve their individual understanding and group collaboration through the development of key group-based practices such as decision making and planning. This presentation reports on a series of semi-structured interviews that were conducted with students at various points in the semester to understand the impact feedback had on them.

PAR-A.04: 11:30 a.m.-12:30 p.m. Topical, Randomized Quizzes in Electromagnetism

Contributed – David E. Pritchard, Massachusetts Institute of Technology, Cambridge, MA 02139

Alexander J. Shvonski, Yunfei Ma, Massachusetts Institute of Technology

Byron C. Drury

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. Finally, we sought to determine what problem variants, if any, were statistically significantly different from their counterparts within a problem. 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.

PAR-A.04: 11:30 a.m.-12:30 p.m. What do Physics Pretests Measure?

Contributed – Dona Sachini Hasanjalie Hewagallage, West Virginia University, Morgantown, WV 26506-6315

John C. Stewart, West Virginia University

This study examines the predictive power of different parameters on FMCE (Force and Motion Conceptual Evaluation) pretest score. The sample consists of students attending a large eastern land-grant university in the U.S. enrolled in the introductory calculus-based mechanics class (N=2457). A variety of parameters were used to predict FMCE pretest score including gender, underrepresented minority status, first-generation status, high school GPA, college GPA, ACT/SAT score, college math entry level, AP classes taken, transfer credits, class standing, prerequisite course grade, and college credits completed. Correlation analysis and linear regression were used to understand relations between the variables. Several parameters were statistically significant explaining the variation of FMCE pretest score including AP classes taken, class standing, and calculus-readiness.

Session PAR-A.05: PER: Diversity, Equity & Inclusion

Sunday, July 19, 11:30 a.m.–12:30 p.m.

Sponsor: AAPT

PAR-A.05: 11:30 a.m.-12:30 p.m. Comparing Attitudes of Students and Faculty About Inclusive Teaching Practices

Contributed – Dan Oleynik, University of Central Florida, Bloomfield, MI 48323

Jacquelyn J. Chini, Erin Scanlon, University of Central Florida

People inherently vary in terms of their needs, abilities, and interests. Previous research indicates that physics instructors hold negative views about people with disabilities, complicity engage in practices of ableism, and do not receive training about teaching or implementing inclusive teaching practices. However, we can support learner variability by employing inclusive teaching practices (i.e., teaching practices that support learner variation, possibly reducing though not eliminating the need for individual accommodations). Using a modified version of the Inclusive Teaching Strategies Inventory (ITSI), we surveyed 140 students and instructors from 10 APS meetings about their beliefs about and use of inclusive teaching strategies. Students and instructors both exist within the same postsecondary environment, while playing different roles. Thus, there may be similarities as well as differences in their beliefs. We will present a comparison of students' and instructors' beliefs regarding inclusive teaching practices.

PAR-A.05: 11:30 a.m.-12:30 p.m. How Data Guided Pedagogical Changes Can Help Traditionally Under-served Populations

Contributed – Christopher Fischer, University of Kansas, Lawrence, KS 66045

Sarah Rush, Jennifer Delgado, Matt Richard, University of Kansas

We collaborated with our university's office of institutional research to assess pedagogical changes in our calculus-based introductory physics courses using different sets of student data. We found that switching to a competency-based grading system in these classes reduced the drop/fail/withdrawal rates and course-associated grade penalties of under-represented minority, first generation, and female students. We separately performed a longitudinal study to identify how changing the curriculum of these physics courses affected student performance in downstream engineering courses. We found that increasing the calculus content in introductory physics correlated with higher grades earned in subsequent engineering courses, and that these downstream benefits were largest for students with lower math abilities. Taken together, these results demonstrate how instructors can use educational data sets to make improvements in their courses that specifically target improving the performance and retention of traditionally under-served populations.

PAR-A.05: 11:30 a.m.-12:30 p.m. Practicing Physicists' Knowledge about Disability

Contributed – Erin M. Scanlon, University of Central Florida, Orlando, FL 32825

Jacquelyn J. Chini, University of Central Florida

Disability is an important dimension of human diversity. Previous research indicated that physics instructors receive little training about supporting people with disabilities, physics curricular materials are not designed to support students with disabilities, and STEM professionals hold more negative views about people with disabilities than their peers in other academic disciplines. The purpose of this study was to investigate the knowledge possessed by practicing physicists about people with disabilities and different types of impairments. We collected data at 10 American Physical Society meetings via a home-grown survey, the Disability and Physics Career Survey. Specifically, 208 participants were given a list of disability diagnoses (e.g., attention deficit-hyperactivity disorder, blindness, amputated limb) and were tasked with selecting the category of impairment (e.g., cognitive, visual, mobility) that the diagnoses belonged in. If practicing physicists are not knowledgeable about diagnoses and/or categories of impairment, they will be less likely appropriately mentor students with disabilities.

PAR-A.05: 11:30 a.m.-12:30 p.m. Promoting Inclusion Through Reflective Journaling in Introductory Physics

Contributed – Ana M. Barrera, San Francisco State University, San Francisco, CA 94132

Kimberly Coble, San Francisco State University

At San Francisco State, the Alma Project was created to support connections to students' life experiences and affirm their identities 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, allowing over 1000 students to share their experiences in STEM spaces each semester. Through instructor interviews we identify implementation challenges and success as well as the perceived effect of reflective journaling on the classroom environment. Interview questions also allowed instructors to reflect on their teaching practices and ways in which they support and encourage a sense of belonging in their classrooms.

PAR-A.05: 11:30 a.m.-12:30 p.m. Surveying Physics Instructors' Attitudes and Beliefs about Inclusive Teaching Practices

Contributed – Jacquelyn J. Chini, University of Central Florida Orlando, FL 32816

Dan Oleynik, Erin Scanlon, University of Central Florida

Postsecondary STEM education and STEM education researchers rarely center the experiences and needs of students with disabilities. Thus, it is not surprising that postsecondary STEM education is not designed to support students with disabilities, and students with disabilities are underrepresented in STEM. Inclusive teaching practices support learner variation, possibly reducing though not eliminating the need for individual accommodations. We used a modified version of the Inclusive Teaching Strategies Inventory (ITSI) to investigate physics instructors' views about and use of inclusive teaching practices by recruiting practicing STEM professionals from American Physical Society Division and Section meetings and listservs. In this talk, we present preliminary findings about strategies that instructors frequently identified as important/not-important and strategies they self-identified as using/not using. Additionally, we explore variations across "who" respondents described they would use the instructional practices for and argue that instructors should avoid implementing strategies only for an instructor-defined "students who need it".

PAR-A.05: 11:30 a.m.-12:30 p.m. Using Universal Design for Learning to Identify and Implement Inclusive Practices

Contributed – Westley D. James, University of Central Florida, Orlando, FL 32816-2385

Sacha Cartagena, Jillian Schreffler, Eleazar Vasquez III, Jacquelyn J. Chini, University of Central Florida

Students with disabilities make up between 10-20% of postsecondary students, however instructors lack knowledge about how to support this population and little research has investigated how courses can be designed to support students with disabilities. Universal Design for Learning (UDL) is one framework we can use to identify barriers to learning in our courses and identify strategies that reduce these barriers. UDL supports the reduction of barriers to learning by providing guidelines and checkpoints which provide considerations and recommendations for supporting the variability of students' interests, needs, and abilities. We will present how the UDL framework was used in observations of postsecondary, introductory physics courses to identify barriers to learning. We will then exhibit inclusive practices that the instructors for the observed courses chose to implement in response to feedback from the observations, along with how students responded to the implemented practices.

PAR-A.05: 11:30 a.m.-12:30 p.m. Women of Color and LGBTQ+ Women's Discussions of Support Systems Available at Two HSIs*

Contributed – Xandria R. Quichocho, Texas State University, San Marcos, TX 78666

Jessica Conn, Erin M. Schipull, Eleanor W. Close, Texas State University

Identity development is critical to student retention in physics degree programs. Historically, research on physics identity in Physics Education Research has been conducted at Predominately White Institutions and has largely ignoring the unique identity intersections experienced by women of color, and women who identify as Lesbian, Gay, Bisexual, Transgender, and Queer. The research team conducted semi-structured interviews with women who identify as racial minorities and/or as LGBTQ+ at two Hispanic Serving Institutions located in Central Texas. We apply a critical and intersectional lens to analyze the narratives and aim to identify the systemic structures provided by these institutions. We will present data highlighting the various systems that exist that aid in the continuous support and intersectional physics identity development for multiply-marginalized women that ultimately lead to their academic and social success in the field.

*This work has been supported in part by NSF grants DUE-1557405, DUE-1557276, and PHY- 0808790.

PAR-A.05: 11:30 a.m.-12:30 p.m. Workplace Climate for LGBT+ Physicists:Predictor of Outness

Contributed – Matthew J. Mikota, Department of Physics and Astronomy, he University of Utah

Ramón Barthelemy, Department of Physics and Astronomy, The University of Utah

We analyzed the climate experiences of LGBT+ physicists through an online survey (N=324) collected by the committee on LGBT+ physicists for the American Physical Society. Results demonstrated the impact of workplace climate (positive and negative), the observation and experience of exclusionary behavior, and status as a student on how out physicists were about their LGBT+ identity. We found that being a student, exposure to exclusionary behavior, and both positive and negative workplace climate were significant predictors of outness to coworkers. The climate model can explain 22% of the variance in outness using these significant features. The results indicate that a positive workplace climate is a strong predictor of outness suggesting the further importance of proactively inclusive physics communities.

Session PAR-A.06: PER: Student Content Understanding, Problem-Solving and Reasoning

Sunday, July 19, 11:30 a.m.–12:30 p.m. Sponsor: AAPT

PAR-A.06: 11:30 a.m.-12:30 p.m. Assessment of Knowledge Integration in Learning Geometric Optics

Contributed – Yue Xiao, The Ohio State University, Columbus, OH 43210

Jian Wen Xiong

Lei Bao

A key strategy in solving geometric optics problems is drawing ray diagrams. However, through interviews with middle school teachers in China, it appears that the ray diagram is not emphasized in instruction due to the fact that most problems homework and exams can be solved by memorizing the final results of special cases (such as the three special rays that go into a lens). As a result, students did not make the connection between the principles of geometric optics and the final results that they memorized. In this talk, a conceptual framework on geometric optics is introduced to map out students' knowledge structures. Based on the conceptual framework, a multiple-choice test is designed to further probe students' conceptual understanding. Assessment outcomes will be discussed to shed light on new instruction methods that emphasize the ray diagram method for achieving deep understanding of geometric optics.

PAR-A.06: 11:30 a.m.-12:30 p.m. Assessment of Student Learning of the Hand Rules in Electromagnetism

Contributed – Yikun Han, The Ohio State University, Columbus, OH 43210*

Lei Bao, The Ohio State University

Feipeng Pi, Guangzhou University

In the Chinese high school physics curriculum, the Ampere's rule, the left-hand rule, and the right-hand rule are used to determine the direction of the magnetic field, the ampere and Lorentz force, and the direction of the electric current. However, without a deep understanding of the basis of these rules, which arises from the concept of cross-product, it is easy for students to confuse these rules. This leads to inefficiency and difficulty in problem-solving, which is also the difficulty faced by most teachers. The central idea of these three rules is the cross product; therefore, by guiding students to establish the concept of cross product can cultivate deep learning of electromagnetism knowledge. In this presentation, a conceptual framework of the hand rules will be instructed along with an assessment tool that evaluates students' understanding of the mastery of the three rules at different phases of their learning.

*Sponsored by Lei Bao

PAR-A.06: 11:30 a.m.-12:30 p.m. From Cartesian to Hilbert Space: Improving Understanding of Qantum Bases*

Contributed – Benjamin P. Schermerhorn, California State University, Fullerton, CA 92831-3599

Giaco Corsiglia, Steven Pollock, University of Colorado Boulder

Homeyra Sadaghiani, California Polytechnic University Pomona

Gina Passante California State University Fullerton

The meaning and representation of basis is fundamental to many quantum mechanics topics, including probability, measurement, and time evolution. Furthermore, students are often required to change the basis of a state in order to gain other information about a system. Data collected from "spins-first" courses across three institutions has illuminated a variety of challenges for students, related to procedures, interpretation, and notation. To help improve student understanding, we designed an activity that makes an analogy between spin basis vectors and more familiar two-dimensional Cartesian unit vectors. In this activity, students draw vectors for a state and discover that changing the basis is analogous to using a different set of coordinate axes to represent the same state. We provide evidence that this activity supported students in their understanding of basis representation and in the procedure of changing basis.

*This work has been supported in part by the NSF under Grants No. DUE-1626594, 1626280, and 1626482.

PAR-A.06: 11:30 a.m.-12:30 p.m. Inevitably Uncertain: Student Reasoning About Measurement Uncertainty

Contributed – Courtney L. White, California State University-Fullerton, CA 92831

Emily Stump, N.G. Holmes, Cornell University

Gina Passante, California State University-Fullerton

Measurement is a concept that students are familiar with well before they enter university. However, measurement and uncertainty are widely misinterpreted by students in physics laboratory settings. In this work we investigate student reasoning about the distribution present in experimental data. We analyze semi-structured interviews with advanced physics students where they were asked to explain the distribution in a fictitious data set. Our coding focuses on whether or not students think there is a true value that can be measured and how they believe the distribution can be reduced (or eliminated).

PAR-A.06: 11:30 a.m.-12:30 p.m. Relating Solutions to the Heat Equation to the Underlying Physics

Contributed – Mieke De Cock, KU Leuven, Heverlee, 3001 Belgium

Paul van Kampen, Dublin City University

Sofie Van den Eynde, KU Leuven / RU Groningen

Johan Deprez, KU Leuven

Martin J Goedhart, RU Groningen

Interpreting and understanding the way students use and understand the mathematics used in physics is a central theme in Physics Education Research. Physical phenomena described by partial differential equations (PDEs) provide a promising context to study how students combine physics and mathematics. An example is the description of heat flow and temperature distribution in a one-dimensional rod, which can be described by the (1D) heat equation, together with an initial condition (IC), and boundary conditions (BCs). In this contribution, we present data from an interview study where we gave students the mathematical description of a system (PDE, IC and BCs) together with the analytical solution. We asked to describe the time evolution of the system, both in mathematical and physical terms. Our analysis shows that students' reasoning is mainly mathematical with little reference to the underlying physics and that most students do not connect their mathematical statements to physical processes.

PAR-A.06: 11:30 a.m.-12:30 p.m. Shared Resources in Student Understanding of Spherical Unit Vectors: Examples

Contributed Brant E. Hinrichs, Drury University, Springfield, MO 65802

Ying Cao, Drury University

The previous talk introduced and elaborated on the theoretical framework of shared resources in the context of students solving problems about spherical unit vectors in upper-division E&M. In this companion talk, we discuss additional examples that we have identified from three small group think-out-loud interviews on the same topic, and go into greater detail about how these resources speak to their ability to navigate through some of the difficulties of this extremely challenging concept. We conclude with some implications for possible instructional strategies.

PAR-A.06: 11:30 a.m.-12:30 p.m. Shared Resources in Student Understanding of Spherical Unit Vectors: Theory

Contributed – Ying Cao, Drury University, Springfield, MO 65802-3791

The resources framework has been applied in physics education research in many different contexts. While it focuses on the thinking of individuals, in this work we instead apply an expanded framework called shared resources to look at a small group as they solve problems together related to spherical unit vectors in the context of upper-division E&M. Using examples from this think-out-loud interview, we illustrate what we mean by the theoretical lens of shared resources: what they are, how they are shared, and what role they can play in helping students make sense of a difficult physics topic. This work extends previous work by including more substantial and more in-depth analysis from a richer example

PAR-A.06: 11:30 a.m.-12:30 p.m. Spanning the Space of Student Ideas on Change-of-Basis in Quantum*

Contributed – Giaco Corsiglia, University of Colorado Boulder, Boulder, CO 80309

Benjamin Schermerhorn, Homeyra Sadaghiani, Gina Passante, California State University Fullerton

Steve Pollock, University of Colorado Boulder

Representing a state in an observable's eigenbasis encodes probabilities for measurement outcomes and facilitates computation of useful quantities such as expectation values. Converting state vectors between bases is therefore a key skill for students in quantum mechanics. Our research in upper-division quantum mechanics courses at three diverse institutions investigates student understanding of basis and change-of-basis in the context of spin-1/2 systems. Our investigation focuses on procedural and conceptual written questions as well as student reasoning interviews. We identify the range of methods students employ when changing basis, illuminate student understanding of the structure and meaning of a basis expansion, enumerate student ideas about whether and how changing basis affects the state, and examine how students perceive notation as indicative of choice of basis. Together, these results paint a broad qualitative picture of the various ways students grapple with basis and change-of-basis, with potential implications for instruction.

*This work has been supported in part by the NSF under Grants No. DUE-1626594, 1626280, and 1626482.

PAR-A.06: 11:30 a.m.-12:30 p.m. Technical-Vocational Education (TVE) Students' Mental Models about Electric Circuits

Contributed – Voltaire M. Mistades, De La Salle University, Manila, MNL 0922 Philippines

Jasmin Elena B. Orolfo, St. Jude Catholic School

The study looked into the conceptions and misconceptions about electric circuits of students taking an electricity-related program in a technical-vocational education (TVE) high school. The study showed that majority of the students have misconceptions and incomplete conceptions about electric circuits and the elements that make a circuit work. While they showed familiarity with actual circuit elements, they lacked familiarity with the symbols used in an electric circuit. The TVE students had varied understanding about how energy flows in an electric circuit. Some students subscribed to the Unipolar Model, the idea that electrical energy flows from the negative terminal only. The Bipolar Model was also present among the students, with the students describing the current from the positive terminal moving faster than the current that flows out of the negative terminal. The students' self-constructed idea about what happens when the energy reaches the load is analogous to a two-way traffic model.

PAR-A.06: 11:30 a.m.-12:30 p.m. The Conceptual Framework Approach for Modeling Deep Learning in Physics

Contributed – Lei Bao, The Ohio State University, 1 Columbus, OH 43210-1117

Joseph Fritchman, The Ohio State University

Kathleen Koenig, University of Cincinnati

Research has shown that traditional instruction often falls short of helping students develop deep understanding in learning physics. To support the assessment and instruction that promote knowledge integration and deep learning, a new modeling approach, the Conceptual Framework, has been developed, which establishes models of plausible student knowledge structures that focus on the core idea(s) and sub-dime,nsions for a given concept. Assessments based on conceptual frameworks focus on determining what connections students exist for students in both familiar and novel problem formats, while instruction based on conceptual frameworks suggests which material to teaching in order to best facilitate building expert-like connections within the students' knowledge structures. This presentation will introduce the conceptual framework approach and review the recent studies that have shown promising outcomes from applying this method.

*Supported in part by the NSF IUSE-1431908 and IUSE-1712238

Session PAR-A.07: Professional Skills for Students

Sunday, July 19, 11:30 a.m.–12:30 p.m.

Sponsor: Committee on Research in Physics Education Co-Sponsor: Committee on Graduate Education in Physics

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 PAR-A.08: Promoting and Supporting Equity and Inclusion in STEM Introductory Courses

Sunday, July 19, 11:30 a.m.–12:30 p.m. Sponsor: Committee on Diversity in Physics Co-Sponsor: Committee on Women in Physics

PAR-A.08: 11:30 a.m.-12:30 p.m. Characterizing Conceptual Understanding in Introductory Physics using Funds of Knowledge, Mental Models and Resource Framework

Invited – Juniar Lucien, University of Michigan, Department of Applied Physics, Ann Arbor, MI 48104

Science education studies framed around funds of knowledge, mental models and student resource framework appear to have three general characteristics: they are learner centered, tend to deviate from the deficit student model of teaching that present learners as empty vessels, but rather present learners as individual beings with different sets of skills and needs. However, there is not a consensus on the ways, as far as we know, in which these three concepts relate with each other. We conduct a systematic inquiry of the literature available for how funds of knowledge, mental models, and resource framework are respectively used in science education, and present a scheme relating these three frameworks that can be utilized when evaluating students' ideas about physical concepts such as energy. Considering how those frameworks connect with one another might provide additional avenues to further explore how students' conceptual understanding of the physical world are formed.

PAR-A.08: 11:30 a.m.-12:30 p.m. Rethinking Foundational STEM Courses: Pulling Weeds or Growing Deep Roots?

Invited – Timothy McKay, University of Michigan, Ann Arbor, MI 48109

At research universities, foundational STEM courses are offered to hundreds or even thousands of students every year. Unfortunately, success in these courses is neither universal nor equitably distributed. Development of such courses and research into their efficacy should be a shared endeavor, yet it often takes place only locally - one discipline and one campus at a time. The Sloan Equity and Inclusion in STEM Introductory Courses project aims to change this. Motivated by a focus on equity, inclusion, and excellence as central goals of the reform process, SEISMIC brings together more than a hundred individuals from ten institutions in a collaborative structure inspired by 'big science' research projects. This talk will describe the emergence and early progress of this R&D project, including parallel data analysis, coordinated experimentation, continuous exchange of speakers, and extended annual meetings.

PAR-A.08: 11:30 a.m.-12:30 p.m. Why Is It Critical to Focus on Making Physics Classes Equitable and Inclusive?

Invited – Z.Yasemin Kalender, Ithaca, NY 14853-2801

Emily Marshman, UChristian Schunn, Timothy Nokes-Malach, Chandralekha Singh, University of Pittsburgh

The discipline of physics suffers from low diversity at all educational levels. Our research seeks to understand the issues related to representation of women in physics related fields and to enhance diverse groups of students to advance and succeed in physics and related fields. In this talk, we will describe the role of students' motivational characteristics in introductory level calculus-based physics courses. These studies aim to understand observed gender differences in students' motivational factors that may arise, e.g., from societal biases against women's ability to excel in physics. We will also discuss the link between prior knowledge and students' learning outcomes across different student demographics and how motivational factors can explain this mechanism. We will describe how we use quantitative tools, such as Structural Equation Modeling, to evaluate complex models of student characteristics, attitudes as well as student learning outcomes. Finally, we will also describe how small and large-scale interventions can mitigate the representation issues, and can create inclusive and equitable learning environments.

Session PAR-A.09: TA Training and Innovations to Make Introductory Labs Work

Sunday, July 19, 11:30 a.m.–12:30 p.m.

Sponsor: Committee on Graduate Education in Physics Co-Sponsor: Committee on Educational Technologies

PAR-A.09: 11:30 a.m.-12:30 p.m. Creating Supplemental Teaching Material for Teaching Assistants

Invited – Darsa Donelan, Gustavus Adolphus College - Saint Peter, MN 56082

There are as many ways to go about instructing a lab as there are teaching assistants. What we hope for our TAs to gain as lab instructors is to come into their own identity as teachers and the ability to effectively communicate scientific work. In this presentation, I will discuss material I have implemented to provide TAs the opportunity to practice their teaching skills while also benefiting from their teaching experience. One project was creating an instructor's guide to laboratories written by former TAs. Written as a refresher for TAs who already have familiarity with the laboratory course, the primary goal is to save them time and effort so that they can focus on the matter at hand: helping the students take as much as they can from the course. I will also discuss the use of supplemental videos that allow TAs and students to visualize portions of the lab.

PAR-A.09: 11:30 a.m.-12:30 p.m. GTA Training: Promoting Inclusive Environments and Students' Sense of Belonging

Invited – Caitlin Kepple, San Francisco State University, San Francisco, CA 94132-2168

Kim Coble, San Francisco State University

The Physics and Astronomy Department at San Francisco State University has recently implemented a pedagogical training course for incoming graduate teaching assistants (GTAs). Using student surveys, we investigate various contributors to students' sense of belonging and compare to testimonies from GTAs (in the form of surveys and interviews) about how they attempt to foster a sense of belonging for their students in lab. We find similar emergent themes in both student and GTA data. After implementing the training course, we found that GTAs were able to cite both a wider range and higher number of pedagogical techniques to create an inclusive classroom. We also found that the testimonies of GTAs who took the pedagogy course were more closely aligned with that of their students' about how to promote a sense of belonging in lab.

PAR-A.09: 11:30 a.m.-12:30 p.m. Impact of Practice in a Mixed-reality Classroom Simulator on GTAs' Questioning Strategies

Invited – Constance M. Doty, University of Central Florida, Orlando, FL 32816

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

In this study, we investigated the impact of practicing with questioning strategies in a mixed-reality classroom simulator on GTA use of questioning both in the simulator and in their actual classroom. During the simulator training, GTAs were in a physical classroom interacting with five avatar-students on a computer monitor. Throughout the fall 2019 semester, GTAs participated in four practice sessions, which were video-recorded. GTAs were tasked with practicing specific teaching skills, and one of the sessions focused on questioning strategies. In each session, GTAs were given two 7-minute opportunities; feedback and reflection time were provided after each 7-minute practice. In addition, GTAs were observed three to four times throughout the semester in their actual classroom. Here, we report frequencies and discuss examples of questioning strategies implemented by GTAs in the simulator and in their classroom. The results suggest that the simulator training supports GTAs' implementation of questioning strategies.

PAR-A.09: 11:30 a.m.-12:30 p.m. Roleplaying in GTA Preparation: Microteaching and Lab Simulation

Invited – Emily Alicea-Munoz, Georgia Institute of Technology, Atlanta, GA 30332

First-time graduate teaching assistants (GTAs) are usually nervous about their first teaching assignment. They worry about knowing the material well enough to teach it, they worry about public speaking and getting respect from their students, and they worry about potentially malfunctioning lab equipment, among many other concerns. Since "practice makes perfect," it makes sense to provide GTAs with the opportunity to practice before their teaching duties begin. In this talk, I describe two such activities that are part of the GTA Preparation class in the School of Physics at Georgia Tech. These activities allow the GTAs to take turns performing as teacher/facilitator and as students, providing them with an idea of what to expect in their classrooms. Course assessments over the past several years have shown that GTAs consider these activities to be very useful in preparing them and increasing their teaching self-efficacy.

Session PAR-A.10: What to Say When Students Ask You About Astrophysics

Sunday, July 19, 11:30 a.m.–12:30 p.m.

Sponsor: Committee on Contemporary Physics Co-Sponsor: Committee on Space Science and Astronomy Presider: *Deborah Roudebush*

SUNDAY

PAR-A.10: 11:30 a.m.-12:30 p.m. Engaging Students through Astrophysics – A MultiMessenger Approach

Invited – Margaret Norris, Black Hills State University, South Dakota 57754

As science educators, we strive to teach content that is high-quality, rigorous, engaging, relevant and equitable for all students. Teaching content that includes examples from current scientific research - in astrophysics, for example - can help hit the engaging and relevant goals. At the Sanford Underground Research Facility, we are going deep underground to study the universe through astrophysics. One experiment is searching for elusive dark matter, another experiment is measuring the nuclear reactions which happen as a star evolves, and other experiments are studying the properties of neutrinos. We engage K-12 students in all of these areas, developing curricula, activities and presentations for students that connect the astrophysics research to standards, science and engineering practices and crosscutting concepts such as scale, proportion and quantity. We will bring some examples for participants to try for themselves.

PAR-A.10: 11:30 a.m.-12:30 p.m. What to Say When Students Ask About Gravitational Waves

Invited – Amber Strunk, LIGO/Caltech, Richland, WA 99352

In the five years since LIGO's historic first detection of gravitational waves, these detections have become almost routine with LIGO and Virgo regularly receiving new candidates. The field of gravitational wave astronomy provides an exciting and engaging opportunity to introduce students to astrophysics. In this talk I will give the background knowledge you need to discuss LIGO, gravitational waves, and these historic discoveries with your students.

Session PAR-A.11: Remote Delivery of Introductory Physics Labs Lessons and Victories

Sunday, July 19, 11:30 a.m.–12:30 p.m. Sponsor: AAPT

PAR-A.11: 11:30 a.m.-12:30 p.m. Conducting a Summer Introductory Laboratory on Short Notice Using iOLab

Contributed – Jack A. Dostal, Wake Forest University, Winston Salem, NC 27109

This summer, Wake Forest University's introductory calculus-based physics courses were delivered fully remotely for the first time. The laboratory portion of the course was primarily conducted using the iOLab Wireless Lab System. We moved to the system on relatively short notice. We conducted lab meetings through synchronous sessions on Zoom to introduce each lab. Following the sessions, students worked on the experiments independently or occasionally in pairs. I will report some of the successes and challenges we experienced.

PAR-A.11: 11:30 a.m.-12:30 p.m. Hands-on Lab Experiences With Social Distancing

Contributed – Wolfgang Bauer, Michigan State University, East Lansing, MI 48824-2600

The essence of laboratory experiences is the gathering of data, analyzing data, forming hypotheses, comparing with models and theories, discussion sources of and estimating statistical and systematic uncertainties, and drawing conclusions, usually in the form of a lab report. All of these components have been replicated in a complete set of first- and second-semester laboratory online experiments at Michigan State University, which can be used to enable undergraduate students to obtain authentic laboratory experiences while staying off campus. The availability of these online labs is crucial, even in universities planning to resume on-campus teaching in the fall, because groups of students in high risk groups need accommodations to remain sheltered during the pandemic. All of these experiments do not need special software, can be run on a web-browser on any computer, tablet device, or even smartphone, and in this way do not contribute to widening the digital divide.

PAR-A.11: 11:30 a.m.-12:30 p.m. Hands-On Laboratories in Online Physics: For Now and Post-COVID

Contributed – Martin G. Connors, Athabasca University, Edmonton, AB T6G0R9 Canada

Farook Al-Shamali, Athabasca University

Many instructors have recently been thrust into the online delivery of physics courses. When Athabasca University pioneered distance education physics in the 1990s with standard freshman mechanics and E&M content, labs could not be done remotely. Then, calculators able to control detectors, such as sonic rangers, became available. A "home lab" approach was developed, which later extended to other subjects, allowing students to perform quality physics experiments with real data, using a lab kit borrowed from the library and sent by mail. Through time our highly successful home lab approach has changed to use what are now common household items like smartphones. We discuss how to implement physics home labs now and urge retaining them when "normal" status returns. In the overall adjustment to a post-COVID world, we argue that successes with our home labs show that this approach should become part of the "new normal".

PAR-A.11: 11:30 a.m.-12:30 p.m. Rethinking the Value of Remote Undergraduate Physics Laboratory Work

Contributed – Drew J. Rosen, Stony Brook University, Jefferson, NY 11777

Angela M. Kelly, Stony Brook University

The global pandemic caused by COVID-19 has provoked an abrupt disruption of postsecondary education on an unprecedented scale. The present study reviews the nature of laboratory work and demonstrates how remote labs provide a viable alternative to in-person learning. Nearly every college in the U.S. has transitioned to remote learning in a short time frame. Regardless of when students return to higher education institutions, this disruption will influence the way laboratory-based coursework is conceptualized. With over half a million undergraduate physics students, the advantages of remote learning may expand STEM access to students who may have been traditionally underrepresented. Physics faculty have been generally hesitant to implement online labs for various reasons such as time, inexperience, and questionable rigor. This paper reviews the historical progression of laboratory work in the U.S., with a critique of the evolving nature of its purpose and relationship to students' performance in physics.

PAR-A.11: 11:30 a.m.-12:30 p.m. Teaching the Introductory Laboratories Remotely: Lessons Learned

Contributed – Tatiana A. Krivosheev, Clayton State University, Peachtree Corners, GA 30096-6146

We present our experience of conducting first semester calculus-based introductory physics laboratories remotely in the Spring 2020 semester. Six laboratories were redesigned to give students maximally hands-on experience under the restrains of coronavirus stay-at-home conditions. The video analysis by using Tracker software was used to collect and process the experimental data for most of these labs. The lessons learned allowed us to confidently teach the full semester of the labs remotely the following Summer 2020 semester.

PAR-A.11: 11:30 a.m.-12:30 p.m. Virtual Reality Physics Labs

Contributed – William H. Miner, Palm Beach State College, Boca Raton, FL 33431

Physics labs have been traditionally hands on courses requiting students in the lab to set up specific equipment designed to demonstrate explicit physical phenomena that can then be measured and analyzed. This makes the lab a two-part process. The first is developing the techniques necessary to set up the equipment, understand its functionality, and then use it carefully to take data. The second part is analyzing and interpreting that data to see if it fits the physical phenomena being demonstrated. In general, this part of the lab is done outside the laboratory. Providing the student with a video, a simulation, or simply a data set does not implement the hands on part. The student can have this experience via the use of a virtual reality laboratory. A variety of virtual reality labs for both physics I and physics II will be discussed.

Session PAR-B.01 Best Practices for Developing Scientific Thinking, Reasoning, and Decision-Making Abilities II

Sunday, July 19, 1:30–2:30 p.m. Sponsor: Committee on Laboratories Co-Sponsor: Committee on Physics in Two-Year Colleges

PAR-B.01: 1:30-2:30 p.m. Changes in Student Attitudes and Curricular Benefits as a New Course Activity Becomes Standard

Contributed – Amber R. Sammons, Illinois State University, Springfield, IL 62702

Katie Crook, Raymond Zich, Illinois State University

Rebecca Rosenblatt

An instructional intervention consisting of students interacting with eight short videos on scientific topics was introduced to a general education physics class. The effects of these videos had on student attitudes about science and their scientific reasoning skills were assessed by comparison of pre- and post-test data from the CLASS and Lawson's Test of Scientific Reasoning for two control and three treatment semesters. Initial findings showed improved student attitudes toward science and improved scientific reasoning skills. With continued use of the videos in additional semesters, similar pre-post gains in scientific reasoning skills were observed, however, less improvement in student attitudes toward science was measured. This decrease in improvement of student attitudes as the new course activity became standard has implications for the number of semesters a new curriculum aimed at improving student attitudes should be studied. Most new curricula only report a semester or two of results before wide implementation occurs.

PAR-B.01: 1:30-2:30 p.m. Critical Thinking in Labs: Giving Students Room to Think

Contributed – Mats A. Selen, University of Illinois - Urbana Champaign, Champaign, IL 61820

Katie Ansell, University of Illinois - Urbana Champaign

Improved critical thinking is a widespread objective of education, yet it is difficult to design specific learning objectives that target the process of thinking itself. We propose a model for developing critical thinking skills in the lab that prioritizes student agency and decision-making, developing skills and background knowledge as a foundation for expert-like thinking in the context of these decisions. Students are trusted to make meaningful progress based on their own perceptions, designing tasks where the process is more important than the result, and are graded using rubrics that allow students to take risks without fearing penalties. In this talk, we describe how our lab materials are designed to promote critical thinking, how skills are developed to support it, and our observations of the outcomes of this type of instruction.

PAR-B.01: 1:30-2:30 p.m. Development of a Problem Set for an Assessment of Uncertainty Reasoning: ELUSA

Contributed – Jennifer A. Delgado, University of Kansas, Lawrence, KS 66045u

Keita Todoroki, Christopher J. Fischer, University of Kansas

We present preliminary work on a method of assessing students' level of understanding experimental uncertainty in undergraduate physics laboratory courses. We devised a set of assessment problems in a nested structure, where we isolated each component of what a "major" question asks into a set of stand-alone "minor" questions. By isolating each key step or knowledge as separate minor questions, we find that our method helps identify the specific pitfalls in the training a student has received in lab, providing useful information for revising future lab instructions and curriculum.

PAR-B.01: 1:30-2:30 p.m. Embedding Employability Explicitly in the Undergraduate Physics Curriculum Using Backward Design

Contributed – Andrea C. Jimenez Dalmaroni, Cardiff University School of Physics and Astronomy, United Kingdom

In order to answer the demands of a 21st century society, physics education should provide explicit opportunities for students to acquire the additional knowledge and practise skills that will allow them to be more successful in the workplace. To this end, and using the techniques of backward curriculum design, we developed a new employability module for second year undergraduate students based on active learning. The module provides physics students opportunities to practise graduate attributes, such as problem solving, dealing with complexity, abstraction, communication and other transferable skills, appropriate to any modern professional workplace, and, crucially, essential for success in our current scientifically and technologically driven society. Students are able to enhance their employability skills by developing a reflective and self-management approach towards their performance, generating an increased self-awareness and confidence, while practising team-work, networking and self-promotion. In order to bring the workplace to the classroom, the module also includes presentations from industry

and research institute delegates, and invited speakers from the Business School. Lectures are interactive and consist mostly of self-directed activities, favouring active, collaborative and self-directed learning. Our preliminary results show that this module prepares students to successfully compete for placement jobs and they demonstrated themselves to be well equipped to interact with employers and perform at their highest capabilities when interacting with university leaders and employability experts. In this presentation we will discuss the current module design, detailing our backward design approach, the results obtained in the first implementation, and planned future improvements.

PAR-B.01: 1:30-2:30 p.m. Slow Sound: An Advanced Lab Experience in Critical Thinking

Contributed – David Sidebottom, Creighton University, Omaha, NE 68178

In a simple time of flight experiment, the speed of sound is observed to travel about 5% slower inside a corrugated irrigation pipe as compared with measurements conducted in open air. In addition to teaching students how to operate an oscilloscope to measure a known quantity, we suggest this slowing of sound might provide the sort of unanticipated finding that is a hallmark of recent, inquiry-based learning strategies, championed by Holmes and Wieman, but geared to an upper division, advanced lab audience. We propose an inquiry-based approach to this investigation wherein students must carefully evaluate the error in the measurement, concede that the finding is unexpected and apply critical thinking to decide how to resolve their observation in a second round of open-ended investigations.

PAR-B.01: 1:30-2:30 p.m. Using FCI Data to Develop Impactful Class Activities

Contributed – Andrew E. Pawl, University of Wisconsin-Platteville, Platteville, WI 53818-3099

Careful examination of my students' individual gains on the Force Concept Inventory (FCI) led to the realization that student pretest knowledge on certain key questions appeared to be correlated to enhanced gain during the class. Acting under the hypothesis that addressing those key questions early in the course might result in broader, test-wide gains, I developed two class activities to address one of the key questions. One of the activities is a laboratory experiment and one activity utilizes a PhET simulation. I have tested those activities over the course of four semesters and there is evidence that they significantly increased the class-wide normalized gains on the FCI.

Session PAR-B.02 Computational Thinking in Physics

Sunday, July 19, 1:30–2:30 p.m. Sponsor: Committee on Educational Technologies

SUNDAY

PAR-B.02: 1:30-2:30 p.m. Computational Modeling Physics First: A Progress Report

Invited – Colleen Megowan-Romanowicz, American Modeling Teachers Association, Sacramento, CA 95820

Computers and algorithms have fundamentally reshaped our world in the last few decades. Data is the new oil. NGSS has codified computational thinking as a science practice. Yet programming has yet to penetrate compulsory K-12 schooling in a meaningful way. A number of high school Modeling Physics teachers have been teaching their students to program for two decades. Although teaching programming basics cut into the finite number of minutes they would otherwise have devoted to physics concepts, they valued the trade-off—equipping students with a tool for visualizing abstractions (e.g., EM fields), and for more tightly connecting mathematical, graphical and diagrammatic representations of conceptual models. Five years ago AMTA and AAPT joined forces to adapt HS physics teachers' pioneering work in computing for use in 9th grade Physics First classrooms. This is a report on where we are presently and what we have learned along the way.

PAR-B.02: 1:30-2:30 p.m. Computational Thinking in Introductory Physics: High School and Early College

Invited – Richelle M. Teeling-Smith, The University of Mount Union, Alliance, OH 44601

Chris Orban, The Ohio State University

Computational thinking (CT) is still a relatively new term in the lexicon of learning objectives and science standards. In 2013, the authors of the Next Generation Science Standards (NGSS) included "mathematical and computational thinking" as one of eight essential science and engineering practices that K-12 teachers should strive to develop in their students. (1) There is not yet widespread agreement on the precise definition or implementation of CT, and efforts to assess CT are still maturing, even as more states adopt K-12 computer science standards. (2) In this presentation, we will try to summarize what CT means for a typical introductory (i.e., high school or early college) physics class. This will include a discussion of the ways that instructors may already be incorporating elements of CT in their classes without knowing it. Our intention is to provide a helpful introduction to this topic for physics instructors.

(1) NGSS Lead States, Next Generation Science Standards: By States, for States (The National Academies Press, 2013). (2) Code.org, "2018 State of Computer Science Education," https://code.org/files/2018_state_of_cs.pdf (2018).

PAR-B.02: 1:30-2:30 p.m. Integrating Computational Thinking with Physics. What Does That Mean?*

Invited – Robert Hilborn, Amerian Association of Physics Teachers, College Park, MD 20740-3845 g

Computational Thinking (CT) is used to describe how our approaches to formulating and solving STEM problems is affected by the availability of modern computers. Many educators use CT broadly to include traditional problem-solving skills, persistence, the ability to work in groups, and so on, along with the development of computational algorithms and coding. Given the wide-spread calls for including CT in both K-12 schools and higher education, educators and policy makers have realized there are not enough teachers to provide stand-alone CT courses for all students. Here I argue that there are strong benefits, both practical and educational, of integrating CT with standard STEM courses. Based on the recommendations of the May 2019 NSF-supported conference on Advancing the Integration of Interdisciplinary Computational Thinking in the Physical and Life Sciences, I discuss how that integration might work in physics courses.

*Supported in part by NSF STEM+C 1812860.

PAR-B.02: 1:30-2:30 p.m. Iterative Calculation of the Acoustic Impedance

Contributed – Herbert Jaeger, Miami University, Oxford, OH 45056

Tra Yen Nhu Phan, Haoyu Tian, Miami University

The acoustic impedance is an important quantity in characterizing the behavior of an acoustic system. The acoustic impedance of musical instruments determines the instrument's response to excitation, reveals resonance frequencies, and shows which notes can be played. While the acoustic impedance is easy to calculate for simple shapes, it is very complicated to do so for the shapes of real musical instruments. This talk outlines an interactive method of calculation of the acoustic impedance of an arbitrary shape of an axially symmetric air column by approximating the air column by a series of cylindrical elements. We demonstrate the feasibility of the method by comparing the iterative result with the closed form solution for air columns of simple shape. Moreover, we discuss the calculation of the acoustic impedance of a trumpet-like instrument and show how different parts of the instrument affect its acoustic behavior.

PAR-B.02: 1:30-2:30 p.m. Measuring and Modelling the Motion of a Chain

Contributed – Daniel J. Burns, PASCO scientific, 10101 Foothills Blvd., Roseville, CA 95747

Modern wireless sensor technology coupled with integrated programming tools allow students to measure characteristics of the complex motion of falling chain systems and compare them to predictions created by their Blockly computer code. Because the data collection only takes a few seconds, this can easily be converted to a distance learning activity by providing students with the data files, software, and lab handouts. Programming techniques allow for accurate predictions to be made by introductory students about systems that would otherwise be too complex. We will look at the motion of a chain draped over a pulley and the force of a dropped chain striking the ground. The labs are appropriate for AP and introductory college physics classes. A link to student lab handouts, teacher guides, and sample data files will be provided.

PAR-B.02: 1:30-2:30 p.m. Molecular Dynamics Calculation of Thermal Conductivity and Viscosity

Contributed – Jan Tobochnik, Kalamazoo College. Kalamazoo, MI 49007

Harvey Gould, Clark University

We discuss a simple and novel method due to Müller-Plathe to compute the thermal conductivity and viscosity in a molecular dynamics simulation. The method is easy to explain and provides insight into nonequilibrium steady state processes. The method is discussed in the added chapter to the forthcoming second edition of our text on thermal physics.

PAR-B.02: 1:30-2:30 p.m. Physics Computational Literacy

Contributed – Tor Odden, University of Oslo, Oslo, NO 0316 Norway

Computation is a critical part of professional physics practice and has been shown again and again to be useful for helping student build physics understanding. But, what are the essential elements that allow physics students to productively use computation? I argue that we can use the theory of computational literacy to answer this question. According to diSessa (2000) and Berland (2016), computational literacy consists of three main elements, or pillars: 1) The material pillar, which involves writing and understanding computer code; 2) The cognitive pillar, which involves breaking down problems into a form that can be addressed with computation (also known as computational thinking); 3) The social pillar, which involves communicating with and about computation. Using the physics department of the University of Oslo, Norway, as a case study, I describe what each of these elements can look like and how we can help our students achieve computational literacy in physics

1. diSessa, A. A. Changing minds: Computers, learning, and literacy. (Mit Press, 2000). 2. Berland, M. Making, Tinkering, and Computational Literacy. in Makeology: Makers as Learners Volume 2 (eds. Peppler, K., Halverson, E. R. & Kafai, Y. B.) 196–205 (Routledge, 2016).

PAR-B.02: 1:30-2:30 p.m. Python N-body Simulation of Solar System Dynamics

Contributed – Kyle Slinker, North Carolina School of Science and Mathematics, Durham, NC 27705

Numerical modeling is used extensively in astrophysics and—when used in a classroom—allows students to explore how models are built in physics in general and how model building is facilitated by computational methods in particular. It also exposes them to ubiquitous tools such as Python and Runge-Kutta. Using a relatively simple N-body simulation students are able to go beyond the usual Kepler's Third law introductory descriptions of orbital dynamics and examine 3-body and chaos effects. I will show some cases where students encounter questions which are central to the current state-of-the-art in planetary dynamics research.

PAR-B.02: 1:30-2:30 p.m. Using Conceptual Blending to Model How We Interpret Computational Models

Contributed – Brandon R. Lunk, Texas State University, San Marcos, TX 78666

An important component to fostering computational thinking in the physics classroom involves helping students understand how to use programming code to represent physical models and physical principles—a process that requires one to interrelate knowledge of physics, mathematics, and programming code. In this talk, I will discuss Conceptual Blending as a framework for modeling how we read physical and mathematical meaning into the structural features of programming code and how features of the programming representation can influence student reasoning, both productively and counter-productively. Understanding these detailed considerations as well as avenues for failures in reasoning that novices might encounter can inform the development of instructional interventions, both in-the-moment and pre-designed.

Session PAR-B.03 New Curriculum by K-12 Outreach Programs

Sunday, July 19, 1:30–2:30 p.m.

Sponsor: Physics in Pre-High School Education Co-Sponsor: Committee on Professional Concerns

PAR-B.03: 1:30-2:30 p.m. A Free Renewable Energy-based Physics Camp for Diverse Middle School Girls*

Contributed – Roberto Ramos, University of the Sciences, Philadelphia, PA 19104

A safe, nurturing learning environment, hands-on collaborative learning, interaction with women model scientists, laboratory and industrial plant tours, engagement using novel experiences, and an atmosphere of positive reinforcement were key interventions implemented in a physics camp designed to enhance the physics learning of and disciplinary appreciation by middle school girls. The Physics Wonder Girls Program provided a free, renewable energy physics-based summer camp to two cohorts of middle school girls from the Philadelphia area. Coming from diverse communities, the girls took a crash course on circuits using solar cell kits, and built and raced solar cars and boats. They compared the efficiencies of silicon cells vs. organic solar cells, built solar cells based on dyes from raspberry and blackberry fruit, and used a thermal imager to audit heat leaks. They met women physicists and engineers, toured a local food plant and presented demonstrations to a community of friends and teachers.

*I acknowledge support from Constellation - an Exelon company, and Puratos Corporation. Web: https://sites.google.com/usciences.edu/physicswondergirlscamp/

PAR-B.03: 1:30-2:30 p.m. BYU/UVU-GAL: A Focused Outreach Activity for Young Women

Contributed – Dallin Durfee, Utah Valley University, College of Science, Orem, UT 84058

Since 2013 I have run a multiple-day, focused summer outreach program. The goal of the program is to dispel biases and show junior high and high school aged girls that they have the ability and opportunity to become scientists. The event is designed to give approximately 16 young women an intense, multi-day experience. The small size of the group and the length of the activity allows them to understand and perform in-depth activities. Insights I have gained about successfully running this type of activity will be discussed.

PAR-B.03: 1:30-2:30 p.m. Creating Explanatory and Predictive Models of Magnetism in the Middle-Grades

Contributed – Tamara G. Young, University of Utah, Salt Lake City, UT 84112

Lauren A. Barth-Cohen, Sarah K. Braden, Sara Gailey, Utah State University

There is a growing interest in the scientific practice of Developing and Using Models as it is included in the Next Generation Science Standards (NGSS, 2013). However, often the focus has been on models that capture how a given phenomenon looks, rather than models for explaining and predicting how scientific phenomena work. We developed a curriculum focused on supporting students in creating mechanistic (or explanatory) models of magnetism that can be used to make predictions. In this curriculum, students: explore an anchoring phenomenon, create models, investigate additional magnetic properties while collecting data, revise their models, and finally, through consensus building activities, create a consensus model that they present to the class. We have found that this process allows students to create models of magnetism that are both explanatory and predictive. We will present this curriculum and show examples of student work to help participants use this in their own classrooms.

PAR-B.03: 1:30-2:30 p.m. Nuclear Science for Everyone

Contributed – Zachary Constan, National Superconducting Cyclotron Laboratory, East Lansing, MI 48824

The National Superconducting Cyclotron Laboratory and Joint Institute for Nuclear Astrophysics conduct a host of different outreach programs. Camps offer the experience of being a nuclear scientist to students of (nearly) any age and science teachers. Lessons and games connect nuclear science with current astrophysics topics. Tours offer a close-up view of research in action, while talks are available to groups that can't travel. Museum exhibits make the research truly hands-on, while dance introduces nuclear concepts in a novel fashion for a brand new audience. There truly is something for everyone. Discover the FREE resources available to students & teachers, kids & adults anywhere in the world!

PAR-B.03: 1:30-2:30 p.m. Physics Content and Practices Across the Landscape of Informal Physics

Invited – Dena Izadi, Michigan State University

Julia Willison, Kathleen Hinko, Michigan State University

There are multiple ways for K-12 students to learn about physics and communicate science. One example is informal physics programs, which provide significant science resources in their communities. These programs house unique collections of physics artifacts and experiences for K-12 and are facilitated by educators who are experts at motivating interest and involvement in students. As part of our nationwide effort to develop a systemic understanding of the landscape of informal physics, we have developed a framework to investigate how these programs are structured and facilitated. Our study is focused on a number of important aspects, including the curriculum used by practitioners, how informal physics programs are facilitated, how they are socially constructed, how they attract their audience, and what type of assessment they use to evaluate their own effectiveness. In addition, we will share our experiences combining physics for K-12 students with other disciplines, including art, in program curricula.

PAR-B.03: 1:30-2:30 p.m. PiA – Physics in Advent, A Hands-on Physics Advent Calendar

Invited – Arnulf Quadt, Georg-August-Universitaet Goettingen, Lower-Saxony 37077 Germany*

"PiA - Physic in Advent" https://www.physics-in-advent.org is an Advent calendar of a special kind: a physics Advent calendar. From 1st to 24th December, small physics experiments using household material are presented every day as youtube videos by Mr. Santa or Ms. Santa. Participants do the experiments and answer a question on the PiA website. On the following day, there will be a solution video and possibly a point. After 24th December, all participants receive individual certificates. Among the best participants, prizes will be raffled off in the categories individual, school class or school. „PiA - Physik im Advent" is aimed at children and pupils aged between 11 and 18 years. It is intended to awaken the joy of experimenting and offer education, entertainment, and fun at the same time. In 2019, a new record was set with 43,500 registered participants, 49% of whom were girls, and 1.7 million visitors overall.

*Sponsored by Dr. Dan MacIsaac

PAR-B.03: 1:30-2:30 p.m. Sharing to Learn: Undergraduate Experience in Little Shop of Physics

Invited – Heather Michalak, Colorado State University, Fort Collins, CO 80528

Throughout the Little Shop of Physics' (LSOP's) 29 years, we've shared informal, hands-on science education with over 600,000 K-12 students. This success has been — and continues to be — possible thanks to over 4,000 undergraduate volunteers and interns. All the interactive experiments we take to schools across the country are built and maintained by undergraduates at Colorado State University. These same undergraduates have primary responsibility for interacting with K-12 students during LSOP school visits. Our volunteers and interns come from all majors and backgrounds; this diversity benefits the volunteer and intern cohort, the LSOP, and the K-12 students we work with. In turn, during their time at LSOP, volunteers and interns learn marketable skills, acquire conceptual physics understanding, and belong to an inclusive campus community. Undergraduate involvement is at the heart of LSOP's ongoing cogency; it keeps the program harmonized to current needs of K-12 students.

PAR-B.04: 1:30-2:30 p.m. A First-Year Research Experience for Physics Majors

Contributed – Jonathan L. Bougie, Loyola University, Chicago IL 60660

Faculty in the Loyola University Chicago (LUC) Physics Department initiated the “Freshman Project” in 1996. This project has continued each year until today, becoming a separate one-credit course that is a graduation requirement for majors in the department. Students, generally in their first year in the major, work in small groups with a faculty mentor, carrying out a semester-long investigation designed to model many aspects of the research experience. Students propose an investigation, design and carry out an experiment, conduct theoretical analysis, and present their results at a department symposium. I will discuss the important role this program has played in the growth and development of the Physics Department at LUC, as well as the benefits of engaging students in this activity early in their undergraduate careers.

PAR-B.04: 1:30-2:30 p.m. An Online Physics Course to Empower the Adoption of Open Education Resources

Contributed – Zhongzhou Chen, University of Central Florida, Physics Department, Orlando, FL 32828

Geoffrey Garrido, Matthew Guthrie, Zachary Felker, Tom Zhang, University of Central Florida Physics Department

Our group has created open source online learning modules covering around 95% of common topics in a college level calculus-based mechanics course. These learning modules are hosted on an open-source platform, Obojobo, which can be deployed on a cloud server and integrated with any learning management system supporting LTI standards. The motivation to create this new set of open education resources (OER) is threefold: 1. They blend instruction, practice and assessment together in a mastery-based modular design to improve student learning; 2. The modular design provides higher flexibility and better organizational structure to facilitate, adopt, and reuse OER; 3. Our group is developing methods to analyze student learning data that enable the modules to be continuously improved based on data analysis. In the future, these modules could hopefully replace lectures and textbooks to promote the adoption of active learning practices in the classroom.

PAR-B.04: 1:30-2:30 p.m. Can Extra Credit Effectively Reduce Cramming Behavior for Online Homework?

Contributed – Zachary Felker, University of Central Florida, Orlando, FL 32816-2385

Matthew W. Guthrie, Zhongzhou Chen, University of Central Florida

It is common among many college students to wait until the last minute to complete homework assignments, which leads to insufficient time for study. Can assigning extra credit for early completion of homework assignments alter students’ behavior? We study students’ work habits when completing mastery-based online learning modules for homework by analyzing clickstream data collected from the online learning platform over multiple semesters. In some semesters, students may earn extra credit by completing some of the assigned modules well before the due date in the form of “treasure trove” quizzes. These quizzes receive overwhelmingly positive feedback from students. We examine in what ways the "treasure troves" change student behavior by clustering learning events into sessions using a machine learning algorithm. We examine how duration, number, or event density of clusters differs when “treasure troves” are introduced. We also study their impact on exam scores.

PAR-B.04: 1:30-2:30 p.m. Direct Observation of Student Behavior in Online Learning Modules

Contributed – Matthew W. Guthrie, University of Central Florida, Orlando, FL 32816

Zachary Felker, Tom Zhang, Zhongzhou Chen, University of Central Florida

Interpretation of student behavior in online learning platforms based on clickstream data is complicated by not being able to directly observe the learner. This leads to difficulties in understanding inherently unobservable effects on the students’ clickstream data. For example, we try to calculate the amount of time that each student spent studying the instructional material in each module, which requires estimating certain properties of the resulting data. Consequently, the major issue we address in this work is the difficulty of making reasonable cutoffs for abnormally short and abnormally long events. Students enrolled in introductory mechanics courses participated in a study where they completed online homework modules in a controlled, observed environment. In this talk, we will present comparisons between students’ clickstream data for those who were observed and those who were not observed, and for the same student in proctored and non-proctored sessions on different modules.

PAR-B.04: 1:30-2:30 p.m. Examining Student Design Tasks in Research-based Activities

Contributed – Amin Bayat Barooni, Georgia State University, Atlanta, GA 30302-3999

Joshua S. Von Korff, Brian D. Thoms, Zeynep Topdemir, Georgia State University

Jacquelyn J. Chini, University of Central Florida

One goal of physics activities may be to develop student skills in designing experiments. Understanding the use of student design tasks can help instructors who want to use research-based approaches to create new activities. In this research, we analyzed student design actions in 66 research-based activities from 11 different curricula to determine the frequency of various design tasks that students were asked to perform. Our definitions of student design tasks were: 1) describing an experimental procedure invented by the student, 2) improving a previous experiment, 3) making a hypothesis, 4) choosing questions to investigate, and 5) designing, stating, inventing, or improving a mathematical or quantitative procedure.

PAR-B.04: 1:30-2:30 p.m. Examining the Social Dynamics of Small-Group Discussions

Contributed – Muxin Zhang, University of Illinois at Urbana-Champaign, Urbana, IL 61801

Eric Kuo, Gloriana González, University of Illinois at Urbana-Champaign

Group work provides valuable opportunities for students to actively participate in classroom conversations. Instructors often emphasize generating and sharing ideas in group work, but how these ideas are shared in small-group discussions can be complicated by social dynamics within that group. In this project, we applied techniques from Systemic Functional Linguistics (SFL) to analyze the interpersonal meanings in students’ discourse in a college physics lab section. By examining how students socially positioned themselves in the episode, we found that students steered the group’s conversation not only by explicitly offering ideas, but also by positioning as not-knowing, raising questions, and appealing to authority. This episode provides another example to a growing body of research describing the consequential role of social dynamics in how physics students contribute to small-group discussions.

PAR-B.04: 1:30-2:30 p.m. Exploring the Durability of Student Attitudes Toward Interdisciplinarity

Contributed – Gwendolyn G. Rak, Swarthmore College

Benjamin D. Geller, Catherine H. Crouch, Swarthmore College

Building on prior analyses of how introductory physics experiences affect student attitudes, preliminary evidence suggests that IPLS students, more so than their counterparts in traditional introductory physics courses, express the attitude that physics is relevant to their primary biological interests. We report on the durability of these attitudes. We present results from interdisciplinary attitude surveys given to students a year (or more) after their initial experience in IPLS, as well as immediately after that experience. By tracking the evolution of student attitudes over time, we assess whether attitude improvements due to IPLS are in fact stable and long-lasting. We also explore how students’ subsequent coursework in biology or other disciplines may influence these attitudes.

PAR-B.04: 1:30-2:30 p.m. Guiding Student Learning with Data

Contributed – Sujata Krishna, University of Florida, Department of Physics, Gainesville, FL 32611-8440

Asa Levi Pearson

Jason Lokkesmore Pearson

We report on the use of data in guiding student's self-assessment of mastery of the learning objectives. Online homework and assessment are commonly used in introductory physics courses. In a gradebook with multiple assignments it can be difficult for a student to realize where they stand with respect to specific learning objectives. We developed individual student-dashboards for the online and face-to-face physics students with a view to revealing the particular concepts they are yet to master and where the payoff from increased effort is maximized. Pearson and UF partnered over the last 6 months to enable students to view their performance relative to the class average at the learning objective level. We also implemented similar dashboards for groups in the group problem solving sessions with Learning Assistants. We report on how the Learning Assistants used the analytics to structure their study sessions.

PAR-B.04: 1:30-2:30 p.m. Using Interactive Online Modules to Improve Student Outcomes

Contributed – Jeremy Matthew Munsell, Purdue University, West Lafayette, IN 47906

N. Sanjay Rebello, Purdue University

The expertise reversal effect (ERE) is concerned with the relative effectiveness of different presentations of instructional materials for learner's with differing levels of domain knowledge. In this work we present the results of a pilot study meant to develop online instructional modules (OIM) that were made adaptive according to the ERE. N = 185 students enrolled in a first year algebra based physics course were provided instruction by way of an OIM covering the concept of energy. Students were randomly shown a module offering a high level guidance or a low level guidance. Student's were designated as either being high prior knowledge or low prior knowledge post-hoc based on their score on a mid-term exam. Consistent with the ERE, we found that high knowledge students did significantly better when presented with instructional materials using a low level of guidance. This effect was absent for students with low levels of domain knowledge.

Session PAR-B.05 Remote Delivery of Introductory Physics Labs Lessons and Victories II

Sunday, July 19, 1:30–2:30 p.m. Sponsor: AAPT

SUNDAY

PAR-B.05: 1:30-2:30 p.m. Communities of Inquiry: Recreating Important Learner Interactions in Online Courses

Contributed – Christopher Moore, University of Nebraska Omaha, NE 68046-6121

During the anthropogenic disaster of the coronavirus pandemic (COVID19), all courses at universities across the country switched to online modalities mid-semester. At the University of Nebraska Omaha, we have used the Communities of Inquiry (COI) framework as the basis for recreating the interplay between instructor, content, and student presence present in the reformed versions of our face-to-face introductory physics courses. In this presentation, we discuss the COI, the various types of important interactions necessary for high-impact instruction, and specifics on recreating these interactions online for a physics course including a laboratory component. We also present preliminary results showing no significant decrease in student learning resulting from the mid-semester change of format.

PAR-B.05: 1:30-2:30 p.m. Comparison of Student Participation and Experience for Two Online Lab Formats

Contributed – Mojdeh Vahid, Western Washington University, Bellingham, WA 98225-9164*

Andrew Boudreaux Western Washington University

At Western Washington University, labs for the calculus- and algebra-based physics courses were converted to an online format for spring quarter 2020 in response to the COVID crisis. Two different implementation formats were used. One involved required synchronous lab sessions facilitated by a TA, a lab worksheet that served as a learning resource but was not a graded assignment, and a subsequent postlab quiz based on the lab worksheet. The other involved an optional synchronous lab session, a lab worksheet that was collected and graded as a required assignment from each student, and no postlab. In this talk, we describe these formats, report on student participation rates and engagement levels, and share student self-reports of learning value and enjoyment from identical surveys administered for each format. We find that leaving synchronous participation optional resulted in substantially lower participation rates.

*Sponsored by Andrew Boudreaux

PAR-B.05: 1:30-2:30 p.m. Home Lab Project: Cheap, Simple Labs Deliver Complex Lessons

Contributed – Miriam T. Simpson, Cuyamaca College, San Diego, CA 92106

Kevin Graves, Scott Stambach, Wyatt Crockett, Cuyamaca College

The rapid shift to online instruction presented daunting problems, but also an interesting question: What do we REALLY want students to learn from an introductory physics lab? At Cuyamaca College, we decided that we cared that students (1) connected abstract course material to something concrete, (2) understood how to collect, analyze, and present data to test a scientific idea, and (3) could communicate their own scientific understanding. To do this we designed two simulation based labs and a project. The lab project, a multi-part assignment spread over the remainder of the semester, asked students to propose, design, run, and present a lab themselves using tools they had at home or could get safely and cheaply. By providing a few examples and a lot of support, we received some truly remarkable projects ranging from DC motors and electromagnets to pendulums and egg drops. Student feedback was overwhelmingly positive.

PAR-B.05: 1:30-2:30 p.m. Newton´s Laws App in Military School

Contributed – Jose Luis Martínez Díaz, Colombian Air Force - COLAF, Colombia

Dib Ziyari Salek Chaves,Wilmer Chacón Ardila, Damian Felipe Castro Beltran, Lorena Cárdenas Espinosa, Colombian Air Force - COLAF

The Newton´s laboratory is an app created under Unity development platform (C and C ++ language) implemented to COLAF (Colombian Air Force) Cadets, whom allow them to go further in the researching field, improve their skills on the basic fundamentals of physics (Newton´s Laws) for applications in aerospace projects. Military personnel are undergraduate students who are subjected to a rhythm of life of constant physical demand, discipline, stress and mental development that are simultaneously complemented by academic training. The impact of the interaction of the cadets with this implemented tool, the contribution to their professional development and the future influence on the use of new technological applications in the training of the Colombian aerospace leaders are evaluated and the results are presented. This app was implemented as a way of supporting the education system due to the ongoin global pandemic.

PAR-B.05: 1:30-2:30 p.m. Pivoting Introductory Physics Labs Online at a Regional Comprehensive University

Contributed – Christopher N. Varney, University of West Florida, Pensacola, FL 32514-5759

Samantha R. Seals, Aaron Wade, University of West Florida

The COVID-19 crisis caused an abrupt shift to introductory physics lab courses to an online modality, with the last 30% of the lab activities being online. The rapid implementation caused a shift in emphasis on learning goals and involved a range of activities, including PhET simulations, video data collection, analysis of data sets, and open-ended free response conceptual questions. Multiple forms of faculty and student feedback of the rapid implementation in spring informed the development of a full suite of online labs offered in the summer. Further, weekly surveys are completed by students currently enrolled in introductory physics lab courses. In this talk, we will disseminate survey results to date and discuss critical issues for effective online labs with solutions, including how to structure lab activities, establish real-time feedback, avoidance of cheating, limitations of learning management systems, and methods for development of randomized experiments.

PAR-B.05: 1:30-2:30 p.m. Remote Delivery of Introductory Physics Labs Using Scale-Up Approach During COVID-19

Contributed – Eric D Switzer, University of Central Florida, Orlando, FL 32816

Dan P. Oleynik, Josh Forer, University of Central Florida

We present our pedagogical experiences and practitioner recommendations for introductory physics undergraduate laboratories using the Scale-Up methodology, in the context of the sudden adaptation to the online teaching environment due to the COVID-19 pandemic. Specifically, we focus on the challenges of implementing focused critical-thinking labs with a diverse student population and graduate teaching staff ill-prepared for such a quick and forced transition. Given the task of achieving pre-COVID-19 learning objectives without providing physical access to laboratory materials, we examine the demonstrated benefits and disadvantages of several tools, such as technology, university resources, communication methods, and leadership skills.

Session PAR-B.06 PER: Diversity, Equity & Inclusion II

Sunday, July 19, 1:30–2:30 p.m. Sponsor: AAPT

PAR-B.06 : 1:30-2:30 Characteristics of Institutions with Learning Assistant Programs: An Equity Investigation*

Contributed – Alexa McQuade, Department of Physics, Boston University, Boston, MA 02215

Jayson Nissen, Nissen Education Research and Design

Manher Jariwala ,Department of Physics, Boston University

Learning assistant (LA) programs support instructors transforming their courses to use evidence-based instructional strategies. We investigated the types of schools that have LA programs to better understand how the distribution of those programs supports excellent and inclusive education across institutions. We used the Carnegie Classification of Institutions of Higher Education (CCIHE) public database to compare schools with and without LA programs, looking at a variety of institutional characteristics to determine whether the distribution of LA programs is equitable across different types of institutions. We will discuss the implications of our findings and identify areas for future research using critical quantitative perspectives in physics education research.

* Funded in part by NSF grant DUE 1525354

PAR-B.06 : 1:30-2:30 How Technocracy Becomes Visible in Engineering Learning Assistants' Role-plays*

Contributed – Hannah C. Sabo, University of Maryland, College Park, MD 20740

Jennifer Radoff, Chandra Turpen, Andrew Elby, Ayush Gupta, University of Maryland

Technocracy, a problematic world view that values technical abilities and solutions over social ones, pervades engineering. In our pedagogy seminar for Learning Assistants (LA) in an engineering design course, we engaged LAs in role-plays, semi-improvised performances guided by a prompt, around troubles faced by a student team. We draw on audio-video records of a role-play and following discussion from our pedagogy seminar in which LAs, playing as students or an LA, had to contend with both social and technical issues. Using tools from discourse analysis, we analyze how technocracy is both reproduced and challenged during the role-play and following class discussion. The discussion allowed the LAs to reflect on their assumptions and decisions during the role-play. We will present implications for the design and facilitation of role-plays as well as for research studying STEM cultures. *Work supported by NSF Grant 1733649.

PAR-B.06 : 1:30-2:30 Impact of Learning Environment on Male and Female Students' Physics Self-Efficacy, Interest and Identity in Calculus-Based Introductory Physics Courses

Contributed – Yangqiuting Li, University of Pittsburgh, Pittsburgh, PA 15232

Kyle Whitcomb, Chandralekha Singh, University of Pittsburgh

Students' self-efficacy, interest and identity in physics can influence their learning, performance and career decisions. Therefore, we investigated the impact of learning environment on male and female students' physics self-efficacy, interest and identity in calculus-based introductory physics. Findings can be useful in creating equitable and inclusive learning environments in which all students can thrive. We thank the National Science Foundation for support.

PAR-B.06: 1:30-2:30 Physics Career Expectations and Diversity Among Secondary School Students

Contributed – Elizabeth N. Parisi, The College of New Jersey, NJ 08628

Giovanna Masia, Desaree' Vaughan, 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 their perception of the various physics career paths. We paid special attention in our analysis to how a student's demographic data affected these variables. In this presentation, we will detail the trends we found between the students' perception of various physics career paths, their likelihood to pursue a career in physics, and their demographics.

PAR-B.06 : 1:30-2:30 The Impact of Social Comparison Concern on Grades

Contributed – Srividya Suresh, The Ohio State University, Columbus, OH 43210-1117

Andrew Heckler, The Ohio State University

Social Comparison Concern (SCC) is a measurement of how negatively students compare themselves respect to their classmates based on their skill and knowledge of the class. Previous research found that female students, underrepresented minorities, and first generation students reported higher SCC on average, SCC was moderately (negatively) correlated with grade, and SCC mediated the effect of belonging on grade. To further understand SCC, we designed an online intervention by adapting prior motivational intervention designs, and administered a semester-long online SCC pilot intervention study for the first course in the introductory calculus physics sequence at The Ohio State University. Students were divided into SCC treatment or no-treatment control conditions by lecture section. We report on evidence that SCC may be impacting midterm and final exam scores (and vice-versa), especially for lower-scoring students, but the results of our pilot treatment remain inconclusive, and we will discuss our next steps.

PAR-B.06 : 1:30-2:30 Toward Characterizing the Demographics of Introductory Physics Courses [1]

Contributed – Raphael Mondesir, Seattle Pacific University, Seattle, WA 98119

Amy D. Robertson Seattle Pacific University

Recent work by Kanim and Cid [2] suggests that the data used in PER is not representative of students enrolled in physics courses at the national level. Using university-level demographics, Kanim and Cid showed that PER studies oversample from white, wealthy, mathematically-prepared populations of students. What we do not yet know is whether these university-level demographics are representative of introductory physics courses, which are a primary site of research in PER. In this talk, we present data from nine US institutions, comparing the composition of introductory physics classes to aggregate university demographics across a number of social markers, including gender, race/ethnicity, and socio-economic status. Our aim is to make progress in characterizing the demographics of introductory physics courses, which is imperative to deepening our understanding of how social disparity is manifested in physics classrooms and the institutions that host them. We discuss limitations of our approach, including problematizing our use of statistics to make sense of who is enrolling in introductory physics.

[1] This work is supported in part by NSF grant numbers 1914603 and 1914572. [2] Kanim, S., & Cid, X. C. The demographics of physics education research. https://arxiv.org/abs/1710.02598

PAR-B.06 : 1:30-2:30 Using Learning Assistants in a Multidisciplinary Algebra-based Physics Classroom

Contributed – Kathryn L. McGill, University of Florida, Gainesville, FL 32611-8440

Sujata Krishna, University of Florida

We present student learning gains in each of a two-part introductory algebra-based physics sequence for a multidisciplinary student population taught with and without the use of undergraduate learning assistants (LAs). We report on our pilot program design, inspired by the Learning Assistant Alliance model and adjusted to suit the particular considerations of this physics sequence, including student population, class size, and existing course structure. We specifically discuss the results of assigning our LAs to submit written feedback to their groups, as well as issues arising from whether or not the group work is for a grade. Additionally, we discuss the development of our LAs throughout this program, closing with lessons learned and plans for Fall 2020. As we are extremely pleased with the results of this program, we plan to continue it and are glad to offer our experience to the physics teaching community.

Session PAR-B.07 Upper Division Undergraduate

Sunday, July 19, 1:30–2:30 p.m. Sponsor: AAPT

SUNDAY

PAR-B.07: 1:30-2:30 p.m. Computational Physics Projects Related to Weyl's Problem

Contributed – Ken Kiers, Taylor University, Upland, IN 46989-1001

Isaac Bowser, Erica Mitchell, Joshua Kiers, The University of North Carolina

Weyl's problem deals with the distribution of eigenvalues of the wave equation in a bounded domain. The integrated density of states counts the number of states up to a certain wavenumber and has important applications in nuclear physics, degenerate Fermi gases, blackbody radiation, and Bose-Einstein condensation. In the limit of large wavenumbers, the integrated density of states depends only on the volume of the domain and not on its shape. Corrections to this behaviour are well-known and depend on the surface area of the domain, its curvature and other features. We describe several computational projects that allow students to investigate this dependence for three different bounding domains – a rectangular box, a sphere and a circular cylinder. Quasi one- and two-dimensional systems can be analyzed by considering various limits. These projects could be incorporated into courses in quantum mechanics or statistical mechanics, or could stand alone in a computational physics course.

PAR-B.07: 1:30-2:30 p.m. Creating a Math Methods Course with an Integrated Computational Lab

Contributed – Todd Springer, Ryerson University, Toronto, ON M5B 2K3 Canada

I discuss the development of a two semester sequence on math methods for undergraduate physics students at Ryerson University. Effective strategies for incorporating active learning techniques in a highly theoretical course will be presented. The numerical analysis component of the course will be highlighted, and I provide some examples of context-rich computational lab activities which were employed. Student attitudes about the course, as well as general takeaways about how best physics and math courses can support each other will also be discussed.

PAR-B.07: 1:30-2:30 p.m. Examining Student Application of Matrix Algebra and Eigentheory*

Contributed – Pachi Yongkao Her, California State University, Fullerton, CA 92843

Michael Loverude, California State University, Fullerton

Matrix algebra and eigentheory are important mathematical tools that students use in upper division physics courses. In this study, we investigated how students apply matrix algebra and eigentheory in various physics contexts, excluding quantum mechanics. The data collected consist of student written responses taken from a math methods course. We used the Physical-Mathematical Model (Uhden, et al) to categorize each question by the three skills the model presents: mathematization, interpretation, and technical operation. The results from our data show that students have difficulty with mathematizing and interpreting the mathematical and physical system of a matrix equation, but are fluent in technical operations. We will present examples of student responses illustrating student reasoning, and discuss implications for classroom instruction.

*Supported in part by the National Science Foundation under Grant Nos. PHY#1406035 and PHY#1912660.

PAR-B.07: 1:30-2:30 p.m. Graduate Programs in Physics Education Research: A USA-based Survey

Contributed – Mirna E. Mohamed, University of Utah, Salt Lake City, UT 84102

Ramón S. Barthelemy, University of Utah

Alexis V. Knaub Western Michigan University

This article outlines the results of a survey seeking to understand Physics Education Research (PER) Ph.D. programs in the USA. The survey explored research group composition, the number of graduates, courses taken and more. The survey was sent to a list of PER research group leaders created by crowdsourcing from the PER community. Of the 46 PER Ph.D. programs identified and invited to the survey, 25 usable responses were received. The majority of programs were in departments of physics with fewer in schools of education or institutes of science education. Most programs required graduate physics course work, with fewer requiring research methodology courses. Only five required a course in PER. The career trajectories of students were diverse, with the majority going into academic careers. However, a robust minority pursued careers in the private sector. It is important to understand the training and support of new Ph.D.s in PER in order to train the next generation of our community leaders and sustain the field as a whole.

PAR-B.07: 1:30-2:30 p.m. Identifying Productive Strategies for Using Ordinary Differential Equations in Physics

Contributed – Anderson T. Fung, California State University, Fullerton CA 92831

Michael E. Loverude, California State University, Fullerton

ODEs are a fundamental tool for modeling any physical system. Math courses tend to heavily focus on the mechanics of finding a solution. However, upper-division physics courses tend to require students to be able to use an ODE to model a physical system. For many, this transition is not a trivial one. Using the concept image framework developed by Tall and Vinner (1981), we analyzed several semesters' worth of pre-instruction surveys and developed a coding scheme that identifies productive evoked concept images and thus productive strategies. Our preliminary findings suggest that when given an ODE in a physics context, students rarely evoked the general functional definition of an ODE but instead relied on other surface features such as the presence of certain symbols or derivatives. We will show examples of student responses illustrating productive and unproductive strategies.

References: 1.) D. Tall and S. Vinner, Educ. Stud. Math. 12, 151 (1981). Acknowledgements: Supported in part by the Black Family Foundation and the National Science Foundation under Grant Nos. PHY#1406035 and PHY#1912660. Views presented in this presentation belong solely to the authors, and not necessarily to either organization.

PAR-B.07: 1:30-2:30 p.m. Introducing SU(3) Color Charge in Undergraduate Quantum Mechanics

Contributed – Jarrett L. Lancaster, High Point University, High Point, NC 27268

Brandon L. Inscoe High Point University

We present a framework for investigating effective dynamics of SU(3) color charge. Two- and three-body effective interaction terms inspired by the Heisenberg spin model are considered. In particular, a toy model for a three-source "baryon" is constructed and investigated analytically and numerically for various choices of interactions. VPython is used to visualize the nontrivial color charge dynamics. The treatment should be accessible to undergraduate students who have taken a first course in quantum mechanics, and suggestions for independent student projects are proposed.

PAR-B.07: 1:30-2:30 p.m. Qualitative Analysis of Students' Epistemic Framing Surrounding Instructor's Interaction

Contributed – Amogh Sirnoorkar, Kansas State University, Manhattan, KS 66506*

Christopher Hass, Kansas Sate University

Qing Ryan, California Polytechnic University Pomona

Alana Uriarte, DePaul University

As part of a larger study into students solving upper division problems in small groups, we investigated how instructors influence students' epistemic framing in an upper-division electromagnetism class. While existing literature indicates that instructors can influence student's epistemic framing, we are interested in the mechanisms by which that influence occurs. We use the CAMP (Conceptual, Algorithmic, Mathematics and Physics) frames in investigating dynamics of students' frames surrounding the instructor's interaction, tracking frame triplets before, during, and after instructor's intervention during tutorial sessions. We identify instructor behaviors which support students' frames and behaviors which tip them into new frames, and show how the instructor's supporting and tipping behaviors change over the course of the semester.

*Sponsored by Eleanor C Sayre

PAR-B.07: 1:30-2:30 p.m. Teaching Computational Methods in a Flipped Format

Contributed – David Nero, University of Pittsburgh

Undergraduate physics students are often required to take a course in computational methods. I will describe an approach to presenting this course in a flipped format. The background lecture for each topic are moved outside of the classroom, in the form of YouTube videos embedded in interactive Jupyter notebooks. A Jupyter notebook is an open-source web application that combines formatted text, executable code, images, videos, and interactive widgets. A plugin for the notebook, called nbgrader, provides for automated grading of coded assignments. In class, students work in small groups to complete programming challenges, applying the techniques described in the videos. The first two assignments each week included built in automated tests, while the more challenging third assignment does not. This approach provides students with immediate feedback as they develop their coding skills, while also encouraging them to think of ways to debug their own code. Students also complete two larger group projects in place of a midterm and final exam. Surveys of student attitudes showed a preference for the flipped presentation when compared to a traditional section of the course, while learning outcomes were equivalent.

PAR-B.07: 1:30-2:30 p.m. The Amazing Quantum Double Well

Contributed – Daniel V. Schroeder, Weber State University, Ogden, UT 84408-2508

The quantum double well is familiar to most of us as a model of molecular orbitals and of wiggling ammonia molecules. It's also a step toward understanding band structure in periodic potentials, an elementary system that exhibits tunneling, and, when only the lowest pair of states is accessible, a beautiful example of a qubit. As a qubit with wavefunctions, it's the perfect system for making the connection between continuous wave mechanics and discrete matrix methods. On top of all this, a double well in two dimensions provides a good first example of an entangled two-particle state. But how can students actually solve the double well energy eigenvalue equation without getting bogged down in transcendental equations or the WKB approximation? The solution is fast and easy if they have learned any of several numerical methods.

SUNDAY

Session PAR-B.09 Using the Effective Practices for Physics Programs (EP3) Guide and its online communities to improve, review, and assess your department

Sunday, July 19, 1:30–2:30 p.m. Sponsor: Comm. on Physics in Undergrad. Educ.

PAR-B.09: 1:30-2:30 p.m. EP3: A Guide to Departmental Improvement*

Invited – Theodore Hodapp, American Physical Society

To assist physics departments and faculty as they improve undergraduate education, the American Physical Society, in collaboration with the American Association of Physics Teachers, is developing a comprehensive guide for program improvement and evaluation, drawn from research findings and community knowledge. Scheduled for release in late 2020, the guide will provide concise advice on nearly all aspects of undergraduate education including suggestions on how to effectively evaluate impact. The EP3 guide will also offer departments guidance on how to produce detailed evidence of how they plan, evaluate, and improve undergraduate learning to help meet university accreditation requirements or prepare for or conduct external site reviews. This presentation will give a broad introduction to the guide and solicit feedback from the audience on how best to make these materials available to the community.

*This material is based upon work supported by the American Physical Society and the National Science Foundation under Grant Nos. 1738311, 1747563, 1821372. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

PAR-B.09: 1:30-2:30 p.m. Serving as an External Consultant for a Departmental Review

Invited – Neal Abraham, Mount Holyoke College, Whately, MA 01093

Periodic review by a department of its programs can be a rewarding opportunity for reflection, evaluation, and improvement; assisting a department with its review as an external consultant is also rewarding. This presentation will review how to find these rewards with a specific focus on the advantages to departments of using external consultants and suggestions for consultants on how they can be most effective. The advantages of a departmental review lie in taking a systematic approach that includes gathering relevant data on a regular basis, assessing the data regularly, and regularly assessing and revising departmental initiatives designed to achieve desired improvements. Though the detailed planning and development of strategic initiatives are the responsibilities of the department and its institution, external consultants can help a department pay closer attention to trends in their data and outcomes, ask critical questions that may have been overlooked, and direct them to examples of alternative practices and models, in addition to providing useful findings and recommendations. This presentation draws heavily on chapters of the new EP3 guide: Effective Practices for Physics Programs which provides advice and suggestions for both physics departments and external consultants during the departmental review process.

PAR-B.09: 1:30-2:30 p.m. Supporting Program Improvement with a Departmental Action Leadership Institute

Invited – Joel C. Corbo, Boulder, CO 80303

David Craig, Oregon State University Sarah B. McKagan, American Association of Physics Teachers

The Effective Practices for Physics Programs (EP3) Project aims to help physics programs respond to challenges they already face with a collection of knowledge, experience, and proven good practice. In addition to a written guide, the EP3 Project will run a Departmental Action Leadership Institute (DALI), a two-day in-person workshop and year-long virtual community to support department members in leading improvements to their program that align with EP3. Five departments will select two faculty members each to participate in a DALI. These participants will learn to effectively lead a local departmental team, strengthen the capacity of that team to create and sustain change, and help the team to implement and assess their plans—all with the goal of developing a culture of continuous self-reflection, assessment, and improvement in the department. We will discuss the goals, structure, and planned implementation of DALIs in this presentation.

Session PAR-B.10 30 Demos in 60 Minutes **Sunday, July 19, 1:30–2:30 p.m.**

Sponsor: AAPT **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 PAR-C.01 Doing Physics and Being ____ **Monday, July 20, 12:30–1:30 p.m.**

Sponsor: Committee on Diversity in Physics Co-Sponsor: Committee on Professional Concerns

PAR-C.01: 12:30-1:30 p.m. "Doing Physics" and Being a Champion for Diversity, Equity, and Inclusion in the Professional Society Arena

Invited – Arlene Modeste Knowles, American Institute of Physics, College Park, MD 20740

I've spent nearly 30 years navigating the physics and, more recently, astronomy communities advocating within the professional society space for women, people of color, LGBT+ people, and others from marginalized groups so that they might thrive in their educational spaces and careers. At the same time, I've had to navigate these communities from the identity of a Black Woman without a physics degree, which has contributed to the experiences I've had throughout my career and has shaped my approach to this work. In this talk, I'll share some of my views, motivations, and experiences doing DEI work in the professional society space; discuss some of the work I've done including my most recent work leading the AIP Task Force to Elevate the representation of African Americans in Undergraduate Physics (TEAM-UP) project; and reflect on the ways in which each of us can uplift students and scientists from marginalized communities to create a better environment for them and all of us.

PAR-C.01: 12:30-1:30 p.m. Doing Physics and Being a Carny

Invited – Valerie K. Otero, University of Colorado Boulder, CO 80309-0249

I grew up working at the carnival after school since I was 12, where I still work today. In high school, I was counseled into the "career training program," which is where they directed all the brown kids. I asked if I could continue to study calculus in career training and they said, "No, take business math." I said, "No. I won't go." I first found physics my 3rd of 6 years in college. It was math with glitter on top! And…I seemed to belong! I was good at it! I failed my first test though, because I worked 16 hours at the carnival the day before. The upshot is that I gained so much business sense over the years, which has helped me build and sustain programs such as the Learning Assistant Alliance and PEER Physics. I will discuss challenges that come from being a low-income, Chicana in physics.

PAR-C.01: 12:30-1:30 p.m. Doing Physics and Being a Traitor to the White Race

Invited – Dimitri R. Dounas-Frazer, Western Washington University, Bellingham, WA 98225

I am grappling with the Sisyphean task of treason against whiteness. For me, such treason involves explicitly rejecting racial bonding with other white people, as well as deliberately searching for worldviews generated by peoples outside the boundaries of whiteness. In this talk, I elaborate on my understanding of treason to whiteness, the 'race traitor' identity, and connections to my identity as a queer Greek-American physics education researcher. I further describe my experiences as an aspiring race traitor whose family, teaching contexts, and research field are predominantly white. I show how white solidarity operates through both the promise/reality of white privilege and the punishment of treason. Finally, this presentation is an opportunity for me to reflect upon my ideologies and practices in the context of work by bell hooks, Chanda Prescod-Weinstein, James Baldwin, John Garvey, Mab Segrest, Noel Ignatiev, Patricia Hill Collins, and others who have influenced my thinking.

PAR-C.01: 12:30-1:30 p.m. Doing Physics and Being Other

Invited – Zahra Hazari, Florida International University, Miami, FL 33199

Cultural border crossing can stir up feelings of anxiety, pretense, and internal conflict, especially if one feels alien to the culture they are navigating. While individuals can learn to navigate border crossings between cultures, limit their expectations of belonging, and find ways to make meaningful and recognized contributions, the feeling of being "other" is hard to overcome and can be isolating. This has been my experience: feeling recognized but not belonging. For example, I have been identified as the "educator" in physics communities but as the "physicist" in education communities. I have been identified as coming from "somewhere else" in western contexts and as the "American" in eastern contexts. I have been treated as irrationally "religious" in science communities and as overly "analytical" in religious communities. While these experiences are wearisome, they provide substantial opportunities to free oneself from the rigid bounds of any culture.

As a community, we need to be cognizant of the cultural boundaries that we create, often unintentionally, so that we can strive to be inclusive in ways that are meaningful to those who are most different from ourselves.

Session PAR-C.02 Gender **Monday, July 20, 12:30–1:30 p.m.**

Sponsor: AAPT

PAR-C.02: 12:30-1:30 p.m. Attitudes and Approaches to Problem Solving: Gender and Instructional Method

Contributed – Melanie L. Good, University of Pittsburgh, Pittsburgh, PA 15213

Alex Maries, University of Cincinnati

Chandralekha Singh, University of Pittsburgh

To examine the potential changes in attitudes and approaches to problem solving over a semester, we administered a previously validated Attitudes and Approaches to Problem Solving (AAPS) survey both at the beginning (pre) and at the end of instruction (post) in eight large enrollment calculus-based introductory physics classes at a large research university in the United States. We found that all classes exhibited a decline in score on the AAPS but that classes which involved significant use of evidence-based active engagement methods exhibited statistically significantly better scores on the AAPS survey at the end of the course. Equally importantly, unlike broader epistemological surveys, female students were found to exhibit less of a decline in AAPS scores than did their male counterparts in all classes and the AAPS scores were always higher for female students at the end of the course.

PAR-C.02: 12:30-1:30 p.m. Impact of Women in Physics Lesson on Students' Bias Perceptions*

Contributed – Conner Kelley, Texas A&M University-Commerce, TX 75428

Keely Scott, Robynne Lock, Texas A&M University-Commerce

Zahra Hazari, Geoff Potvin, Florida International University

The STEP UP Project is focused on challenging societal beliefs surrounding the roles of women in physics and helping interested young women achieve their goals to become physicists. The movement includes many high school physics teachers across the country. Of many teachers recruited to implement the STEP UP lessons, three returned student essays associated with the Women in Physics lesson. Students wrote essays before and after a class discussion, and we compared the students' pre-assignment response with those of the post-assignment and noted changes, if any, in the students' thoughts on the discouragement of women from studying physics. We compared students' shift in beliefs before and after the lesson and constructed diagrams showing changes between the pre- and post-assignment.

*"This work is supported by the National Science Foundation under Grant No. 1720810, 1720869, 1720917, and 1721021."

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PAR-C.02: 12:30-1:30 p.m. Instructor and Student Gender's Effect on Performance in Introductory Courses

Contributed – Matthew Alan Dew, Texas A&M University, Bryan, TX 77801

Tatiana Erukhimova, William Bassichis, Lewis Ford,Texas A&M University

Jonathan Perry, The University of Texas

Previous studies have shown evidence of a gender gap in performance in introductory physics courses for conceptual assessments, course grades, exams, and homework. This study explores the relation between a student's gender and their performance, and perception of that performance, in both calculus-based and algebra-based introductory physics sequences at Texas A&M University. Investigation of student performance based on gender is done using analysis of variance on student midterm exam grades and final letter grades from multiple instructors' courses from 2008-2018. Student perception of their performance and inclusion in the course was measured through a survey administered in fall 2019. We present results from both parts of this study to try to better understand differences in gendered performance in introductory physics sequences.

PAR-C.02: 12:30-1:30 p.m. Supporting Gender Equity in the STEM Classroom

Contributed – Lynn Jorgensen, Gilbert High School, Mesa, AZ 85209

The fields of science, technology, engineering, and mathematics (STEM) have grown in the past twenty years, while the proportion of women in these fields has not seen the same growth. This article researches how inquiry-based instructional approaches can better support gender-equity in classrooms. It will look at the effects that confidence, group work, and Socratic questioning have on women in STEM courses, and how small changes in instruction can have large impacts on the experiences women have in STEM courses.

PAR-C.02: 12:30-1:30 p.m. Teaching Women's History in Physics

Contributed – Beth Parks, Colgate University, Hamilton, NY 13346-1338

Much effort has been expended to uncover forgotten contributions by women in physics and publicize examples of female physicists to students, largely to help female students see themselves in physics. However, the physicists who formulated the ideas taught in college courses were almost all men, and women's absence from these most important roles will be noted by students. If we don't acknowledge and address their absence, then female students won't feel fully supported in their decision to become physicists, since they'll see women only in less influential roles. We need to discuss the social context in which these most influential physicists worked. Since the necessary combination of educational opportunities, family support, social acceptance, financial means, and employment opportunities were available to a much smaller fraction of women than men, it's no surprise that a small fraction of discoveries were made by women. This talk will present a brief sampling of history, looking at the opportunities of three important male physicists--James Clerk Maxwell, Robert Millikan, and Albert Einstein--and comparing them to their female peers. Just a few minutes of class time are needed to discuss this disparity, and also open the door to discussions of current social conditions.

PAR-C.02: 12:30-1:30 p.m. The Challenges and Joys of Being a Physicist Parent

Contributed – Sarah R. Phan-Budd, Winona, MN 55987-0838

Ashley R. Carter, Amherst College

Emily L. Rice Macaulay, Honors College, City University of New York

Heather M. Whitney, Wheaton College

Laura Tucker University of California, Irvine

While the dearth of women in academic STEM positions has long been known (1) , a recent study found that 43% of women and 23% of men leave full time STEM jobs after their first child (2) . This talk addresses the challenges of maintaining an academic physics career while parenting young children. We are a group of mid-career physicists, in an AAPT-sponsored E-Alliance mutual mentoring group, with ten young children between the five of us. We review the efficacy of programs from our various universities, professional organizations, and research collaborations for parents with small children. We make recommendations for how policies and programs can be improved and expanded. Finally, we suggest personal strategies and tips for surviving and thriving as academic physicists with small children.

(1) National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. 2007. Beyond Bias and Barriers: Fulfilling the Potential of Women in Academic Science and Engineering. Washington, DC: The National Academies Press. https://doi.org/10.17226/11741. (2) Cech, E. A. & Blair-Loy, M. Proc. Natl Acad. Sci. USA 116, 4182–4187 (2019).

PAR-C.02: 12:30-1:30 p.m. Understanding the Local Contexts for the Implementation of STEP UP Lessons*

Contributed –Thomas B. Head, Florida International University, Miami, FL 331860

Raina Khatri, Zahra Hazari, Florida International University

After having implemented two lessons developed as part of the STEP UP project, five teachers were interviewed about their experiences using the materials in their classes. These teachers have unique backgrounds and teach in schools with different social and economic contexts. We triangulated the quantitative outcomes of their students with their interview reflections to determine how local context is associated with student outcomes, particularly students' perceptions of the lessons and the post-high school physics intentions.

*This work is supported by the National Science Foundation under Grant No. 1720810, 1720869, 1720917, and 1721021.

Session PAR-C.03 Get the Facts Out: Changing the Conversation Around Physics Teacher Recruitment

Monday, July 20, 12:30–1:30 p.m. Sponsor: Committee on Teacher Preparation Co-Sponsor: Committee on Physics in High Schools

PAR-C.03: 12:30-1:30 p.m. "So, What Does a Typical Mid-career Teacher Actually Make Anyway?"*

Invited – Drew Isola, Get the Facts Out, Allegan, MI 49010

Wendy Adams, Allison Costley Colorado School of Mines

It turns out that answering the above question is not an easy thing to do. In the GFO project* we are defining a 'mid-career teacher' as a high school teacher in a public school district in the U.S. who has about 15 years experience and has a Masters degree or a Masters plus some number of graduate credits. Finding enough data on the salaries earned by such a teacher is a painstaking process of accessing salary tables district by district and looking up these values. The GFO project has been trying to collect useful data on this topic from a wide range of district types and geographic locations. This talk will present the methods used in this time consuming quest, some of our current results and how these salary values compare with cost of living values and median incomes for those same districts. This comparison more accurately reflects these districts' affordability for the teachers that work there.

*Get the Facts Out is a collaboration between AAPT, APS, ACS and AMTE and is fully funded by NSF #1821710 & 1821462.


Access
the Best
Physics
Teaching Jobs

PAR-C.03: 12:30-1:30 p.m. Get the Facts Out: Resource Updates and Recent Research Results

Invited – Wendy K. Adams, Colorado School of Mines, Street Golden, CO 80401

Savannah L. Logan, Jared B. Breakall, Colorado School of Mines

The Get the Facts Out (GFO) project is a joint effort between four national societies and the Colorado School of Mines to change the conversation around grade 7-12 physics, chemistry, and math teaching careers. We have developed the first ever set of research-based, user-tested STEM teacher recruitment materials. To do this and to better understand best practices around recruiting math and science teachers, GFO has a rigorous research arm. Our research includes the study of both student and faculty perceptions of the teaching profession including development of instruments to measure these. Finally, to measure the effectiveness of the project, we are engaging in a large-scale longitudinal study that includes annual collection of qualitative data from eighteen departments and quantitative data from another 60 departments. Here we will share resource updates and recent highlights of research results. This work is supported by NSF DUE-1821710 & 1821462.

PAR-C.03: 12:30-1:30 p.m. My biggest Project Evaluation Challenge: Get the Facts Out*

Invited – Stephanie Chasteen, Chasteen Educational Consulting, Boulder, CO 80301

Wendy Adams, Colorado School of Mines

Get the Facts Out (GFO) is a complex and ambitious social change initiative. It involves a huge number of people at national scale, across different levels of the system. As external evaluator, it is my (rather difficult) job to evaluate the success of the project, and help it to improve. I will describe my use of "developmental evaluation," where results are intended to provide timely feedback to a rapidly evolving complex project. The evaluation has also been guided by the project's theory of change, and thus addresses questions such as "how well prepared are champions to undertake the work," and "are campaigns faithful to the principles of GFO"? I will discuss the decentralized, embedded evaluation measures we are using (including a Fidelity of Implementation rubric, activity tracking forms, chatbots, and surveys). This talk will be of interest to people with an interest in program design and/or project evaluation and assessment.

*We acknowledge funding from NSF- 1821710 & NSF-1821462 for this project. The external evaluation is conducted through Chasteen Educational Consulting (http://chasteenconsulting.com).

Session PAR-C.04 Integrating Computation into High School Physics

Monday, July 20, 12:30–1:30 p.m. Sponsor: Committee on Teacher Preparation Co-Sponsor: Committee on Physics in High Schools

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PAR-C.04: 12:30-1:30 p.m. Integrating Computation in Science Across Michigan

Invited – Paul W. Irving, Michigan State University, East Lansing, MI 48824

Marcos D. Caballero, Michigan State University and CREATE for STEM Institute (MSU)

David Stroupe, Michigan State University

Niral Shah, University of Washington

Integrating Computation into Science Across Michigan (ICSAM) is an NSF funded project that focuses on supporting teachers who wish to incorporate computational activities into their physics classroom in an equitable way. Teachers from across Michigan come to MSU for one week during the summer to participate in a hands-on computational workshop. The emphasis of the workshop is to build up teachers' efficacy and ability with computation while also focusing on encouraging the teachers to consider the impact on equity that computation can have in the physics classroom. Teachers design a computational activity that they intend to use in their class while also having access to the array of computational activities designed by the other teachers. The teachers then participate in bi-monthly workdays that the ICSAM team tailor to the challenges and needs of the teachers. In this presentation, we report on the workshop design and impacts of the ICSAM project.

PAR-C.04: 12:30-1:30 p.m. Testing the STEMcoding Curriculum in an Intense Two Week Course

Contributed – Chris Orban, The Ohio State University, Columbus, OH 43201

The STEMcoding project (http://youtube.com/c/STEMcoding)* has developed a number of high school level "Physics of Video Games" coding activities that are fusion of PhET-like web interactives and traditional coding activities. A crucial question is whether these activities have an impact on student conceptual physics knowledge. The curriculum was tested in an intensive two-week course at a STEM high school in Columbus, Ohio in January 2020. I briefly overview assessment results from that effort, including what we learned, how the assessments will be improved, and how teachers can participate in the research side of the STEMcoding project. I will also give an update on efforts to develop coding activities that allow students to simulate objects in direct motion videos, and other improvements to our suite of activities.

*The STEMcoding project received support from the 2017 AIP Meggers Award

PAR-C.04: 12:30-1:30 p.m. The Experience of Integrating Computation into the Physics Classroom

Invited – Julie Bennett, Linden, MI 48451-9025*

Integrating computation into the classroom has been an uncharted journey; from learning to code at a week long seminar to encouraging students in the classroom to interpret code and solve problems. Gathering information gained through practice and discussion, I introduced my students to vpython using trinket. Programming activities ranged from moving and creating shapes to using the program to confirm physics homework challenges. The results have been varied as I learn to understand how quickly (or not) students pick up the logic flow of programming. Exposing students to the world of coding is valuable in that no matter where and what they end up doing in their lives, they will be exposed to some need for programming. As an experienced teacher, but not an experienced programmer, I am a great model for "anyone can do this".

*Sponsored by Danny Caballero

Session PAR-C.05 K-12 PER — Monday, July 20, 12:30–1:30 p.m.

Sponsor: Committee on Research in Physics Education **Co-Sponsor:** Committee on Physics in High Schools **Presider:** *Dan Crowe*

PAR-C.05: 12:30-1:30 p.m. Case Study on the Computational Experiences of High School Physics Students

Contributed – Paul C. Hamerski, Michigan State University, East Lansing, MI 48824

Daryl McPadden, Paul W. Irving, Michigan State University

Marcos D. Caballero, Michigan State University, University of Oslo

The recent widespread integration of computation into high school physics classrooms raises questions around how high school students come to use computation for science learning. This presentation examines the experiences and academic identity development of high school students as they take up computational practices in their physics course. Through a multi-level analysis of moment-to-moment classroom discourse, interviews, and broader histories of STEM teaching policy and teacher-driven computational integration, this presentation provides a detailed case study on the computational experiences of students at a racially diverse, suburban American high school.

PAR-C.05: 12:30-1:30 p.m. Studying the Long-Term Effects of Learning Physics Through ISLE

Contributed – Danielle Bugge, Rutgers University, New Brunswick, NJ 08901

Eugenia Etkina, Rutgers University

Today's high school students need to develop abilities and skills that are applicable across many fields. Recommendations from the Next Generation Science Standards (NGSS) call for integrating science practices into learning of normative concepts in science classrooms. In my classroom, students learn physics through the Investigative Science Learning Environment (ISLE) approach. Based on previous studies, we know that ISLE students are capable of developing science-process abilities. However, how do we know if this approach to curriculum design and learning prepares students for success in the workplace? During Fall 2019, I administered a survey to alumni who learned physics through the ISLE approach. In this talk, I report on the findings from this study with regard to what students remember learning, how their mindset changed during their time in the course, and what elements of their experience had an effect on and/or were transferrable to their future courses and careers.

PAR-C.05: 12:30-1:30 p.m. Using PER to Develop and Adapt PRISMS PLUS

Invited – Lawrence Escalada, University of Northern Iowa, Cedar Falls, IA 50613

Christopher Like, Bettendorf Community School District

Jeff Morgan, Juliana Huegerich, University of Northern Iowa

Physics Resources and Instructional Strategies for Motivating Students (PRISMS) is a high school physics curriculum resource that has been used extensively in UNI teacher preparation and professional development. The original PRISMS materials were a collection of 130 high interest activities related to the real-life experiences of high school physics students designed to develop student conceptual understanding and to cultivate student scientific reasoning and problem skills. The enhanced and revised version, called PRISMS PLUS, focuses on complete learning cycles that provide fully integrated experiences that enable students to develop not only their problem solving and inquiry skills but also deep, long-lasting understanding of physics concepts. This presentation will focus on how PER has been used to develop PRISMS PLUS and adapt it to teacher preparation and professional development including alignment with the Next Generation Science Standards.

PAR-C.05: 12:30-1:30 p.m. What Are Students Learning in AP Physics?

Invited – Eric Burkholder, Stanford University, Stanford, CA 94305

Carl Wieman, Stanford University

We examined variations in Force and Motion Conceptual Evaluation (FMCE) pre-class scores according to self-reports of students' high school physics courses. Most students in our unusual sample population had taken an AP physics course, allowing us to calculate the correlation between FMCE scores and AP exam scores. We also carried out regression analyses to determine how FMCE scores and course final exam scores depend on taking an AP course and AP exam scores when math SAT score is included as a proxy of students' general level of college preparation. The results of our analysis suggest that taking AP physics and even scoring well on the AP physics exam may be a rather weak measure of conceptual understanding of physics or the mastery of physics one would expect students to achieve from an introductory university physics course.

Session PAR-C.06 PER: Diverse Investigations — Monday, July 20, 12:30–1:30 p.m.

Sponsor: AAPT

PAR-C.06: 12:30-1:30 p.m. "Diving into a Void:" Student Views of Research

Contributed – Adrienne L. Traxler, Wright State University, Dayton, OH 45435-0001

Jason Deibel, Meredith Rodgers, Wright State University

The Applying Scientific Knowledge (ASK) program recruits science and math majors in their second year, who take a shared research methods class and then conduct research with faculty mentors for two or more semesters. Assessment throughout the program studies students' experiences of research, their STEM community development, and their skill development and academic progress. The question guiding this portion of the analysis was: How do students define or describe the concept of research, and how does that change as they advance through the ASK program? Students were interviewed near the end of the methods class (prior to joining labs), then after one or more semesters of research experience. We will present a preliminary analysis of interview themes from the first two cohorts, focusing on the physics majors and their similarities or differences from other students. We find that students have a mix of career-oriented and personal motivations for pursuing research.

PAR-C.06: 12:30-1:30 p.m. Academic Integrity Regarding Online, Out-of-Class Resources: Student and Instructor Interviews

Contributed – Brandon James Johnson, University of Maryland - College Park, MD 20770

Ayush Gupta, Erin Ronayne Sohr, Andrew Elby, University of Maryland - College Park

Many students' out-of-class learning experience includes using online and social-media resources such as Khan Academy, YouTube, Chegg, GroupMe, and Wikipedia. Most of these resources emerged in the last few decades, change rapidly, and are used widely. These resources and their use by students are understudied in PER. We conducted semi-structured interviews with seven students and four instructors of university-level introductory physics focusing on how they think about the use of out-of-class resources with respect to ethics and learning. Our preliminary analysis suggests that students' stances toward academic integrity in the context of out-of-class resources are entangled in nuanced ways with their stances toward learning in the context of the course, instructional expectations, classroom practices, and a variety of extra-curricular constraints experienced by students. We will present empirical evidence for some of these connections that reflect across our student and instructor interviews and discuss their implications for physics education.

PAR-C.06: 12:30-1:30 p.m. Analyzing Time-to-Degree for Transfer Students at Michigan State University

Contributed – Alyssa C. Waterson, Michigan State University, East Lansing, MI 48824

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 degree-granting institutions. However, the effect of those transfer courses on the time that it takes students to graduate (time-to-degree) is currently not well understood. We have investigated how incoming transfer courses impact students' time-to-degree by defining three independent groups of transfer students: (1) those entering with college level transfer courses, (2) those with only AP level transfer courses, and (3) those without any transfer credit. The time-to-degree has been shown to be statistically different for each of these groups, with students who enter with college level transfer courses graduating the earliest. We have explored differences in time-to-degree for various demographic information (e.g. gender, race/ethnicity). In this presentation, we will discuss these results in addition to the results from regression models that predict a student's time-to-degree.

PAR-C.06: 12:30-1:30 p.m. Applying Social Network Analysis to an Online Community of Practice for Teachers

Contributed – Michael Nadeau, Texas A&M University-Commerce

Bahar Modir, Robynne Lock, William G. Newton, Texas A&M University-Commerce

We take a social network analysis approach to investigate how members of an online teacher community interact with each other through a nine-week classical mechanics summer course. The class, associated with the Master program in physics with teaching emphasis at Texas A&M University-Commerce, requires students to participate in weekly problem solving and biweekly reading reflection discussion boards. We measured the weekly activity level for the community and number of interactions between students, and compared these to the average values determined for the entire semester. We found that the participation of students in problem solving discussions fluctuates from week to week; revealing the activity of the community of practice, influence of student backgrounds, and possible structural features of the course. Comparatively, the reading reflection participation did not show a noticeable variation. In order to gain more insight into our findings we characterized the types of interactions by categorizing student communication.

PAR-C.06: 12:30-1:30 p.m. Assessing Cross-Disciplinary Understanding of Energy Concepts*

Contributed – Andrew Boudreaux, Western Washington University, Bellingham, WA 98225-9164

Todd Haskell, Emily Borda, Western Washington University

The ability of students to apply learned ideas in new settings is an implicit assumption that underlies the structure of most programs of study in STEM, in which introductory coursework in a range of fields serves as a foundation for advanced coursework in a more targeted area. A salient example involves an energy-based model for interactions, in which energy is associated with objects, has various forms, is transferred and transformed during interactions, and is conserved. At Western Washington University, we have developed a pair of multiple choice assessments to gauge student learning of such an energy framework in a physics context, and to then assess student ability to apply this framework in a novel chemistry context. We frame these assessments as a way of conceptualizing cross-disciplinary learning and an associated approach to measuring such learning. This talk will describe the development and piloting of the assessments and share preliminary data.

*Work supported by NSF-DUE 1612251

PAR-C.06: 12:30-1:30 p.m. Biases, Limitations and Focus: Student Perspectives on Subjectivity in Physics*

Contributed – Randeep Basara, South Seattle College, Seattle, WA 98106

Andrea Wooley, Leander Villarta, Abigail R. Daane, South Seattle College

Descriptions of the nature of science contrast the view of physics as objective, unaffected by human influence. In order to better understand students' thinking about the nature of physics, we collected responses to the question, "Do you think physics is objective or subjective?" In this presentation, we compare and contrast the ideas from "Science for All Americans" to students' ideas about the presence of subjectivity in physics. Students, prior to engaging in conversation about subjectivity, tend to describe physics without reference to human influence. After discussing this question with peers, students acknowledge the individual limitations of human perception and focus in research. We argue that an awareness about the influence of structural and individual subjectivity in classrooms can create a robust scientific community and disrupt the current culture that serves to marginalize groups of people.

*This material is based upon work supported by the National Science Foundation under grant no. S-STEM1643580.

PAR-C.06: 12:30-1:30 p.m. Cartoon Clicker Questions in Physics Classrooms to Engage and Enhance Critical Thinking.

Contributed – Kausiksankar Das, University of Maryland Eastern Shore, Princess Anne, MD 21853

This talk describes a holistic pedagogical approach for classroom engagement using concept cartoons. We will also discuss how classroom students translate theory and fundamental classroom knowledge to authentic application with cutting edge research implemented by undergraduates at a Historically Black University. In our project, we developed and assessed cartoons custom designed for classroom instruction and evaluated student engagement while using the cartoons. We further report on student successes achieved through undergraduate research projects.

PAR-C.06: 12:30-1:30 p.m. Dream Jobs and Desired Career Paths of Physics Majors

Contributed – Anne E. Leak, High Point University, High Point, NC 27268-4260

Krystina Williamson, Barnard College

Benjamin M. Zwickl, Rochester Institute of Technology

Physics can be considered a 21st century liberal arts degree where students learn valuable technical and transferable skills they can apply to a range of careers. As part of the APS PIPELINE Network, we examined fields and sectors physics majors were interested in pursuing, their dream job, and what influenced their career goals. Responses from 178 physics majors at 12 institutions were analyzed using descriptive quantitative approaches for multiple-select questions and emergent thematic qualitative approaches for open-ended questions. Initial findings highlight a diverse range of careers students hoped to pursue, yet these tended to center around research even when students were open to both industry and academic sectors. Furthermore, many students indicated desires for careers that would help the world and provide a supportive working environment. Understanding physics majors' desired careers and perceptions of what is possible has implications for how we prepare them for their next steps after graduating.

PAR-C.06: 12:30-1:30 p.m. Gains as a Function of Pre-test Scores

Contributed – Paul J. Walter, Austin, TX 78704-6489

Gary A Morris, St. Edward's University

Eleanor C. Sayre, Kansas State University

Using matched PhysPort data, we assess the utility of plotting gains as a function of pre-test scores on the Force Concept Inventory (FCI). Doing so has the

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advantage of providing nuance regarding differences in populations, whether it be to shed light on the efficacy of instructional methods or equity among different student populations. We empirically compare raw and normalized gains and find for a population of 9,354 students that neither the raw nor the normalized gain is uniform for students of all pre-FCI scores. We suggest alternative methods for quantifying gain, the relative gain, and the relative raw gain, on standardized assessments that overcome this diculty. We compare the relative gain measures to effect size and nd that each contributes to our understanding of gains. The relative gain measures are straightforward to interpret and visualize. We suggest effect size and other gain measures, particularly the relative gain measures, be used in a complementary way to better assess the differences between populations.

PAR-C.06: 12:30-1:30 p.m. Investigating Research Themes, Partnerships, and Funding for the Physics-Education-Research Community

Contributed – Rebecca J. Rosenblatt, AAAS Science and Technology Policy Fellow, Alexandria, VA 22301

Michael M. Rook, National Science Foundation

This study will inform the Physics Education Research community about patterns of research topics, partnerships between researchers, and funding sources for the PER community over the last ten years. The study involves a textual analysis of all PERC proceedings between 2010 to 2019 to identify funding sources and determine patterns. PERC proceedings were selected given the central role of the Physics Education Research Conference to the PER community. PERC proceedings represent the community across scope of project from small to large, across stage of project from beginning to finished, and from new researchers to those established in the field. Findings are contrasted with those from the Learning Sciences community to provide context for understanding the significance of patterns. The goal of this work is to provide insight into the community's history and ten-year trajectory so that the community can consider how to move the field forward in new directions.

PAR-C.06: 12:30-1:30 p.m. Qualitative Analysis of Students' Perceptions of their Self-Efficacy

Contributed – Jillian Mellen, Rutgers University

Geraldine L Cochran, John Kerrigan, Lydia Prendergast, Antonio Silva, Rutgers University

Students' self-efficacy, their confidence in their ability to complete a task, is a good predictor for success and persistence. Previous research indicates that improvements in learning methods can improve student self-efficacy and that classroom dynamics may impact students' self-efficacy by allowing for different kinds of self-efficacy opportunities. In this study, we analyzed interviews from 12 students enrolled in a flipped integral calculus course to understand their perceptions of their self-efficacy and how this related to classroom dynamics and activities. Preliminary findings reveal that experiences in previous math courses, particularly high school, impacted students' perceptions of their self-efficacy in math both positively and negatively, active learning activities increased students' confidence in their ability to do math from their perspective, and verbal persuasion (implicit encouragement) increased students' confidence and was seen as a helpful way to learn.

PAR-C.06: 12:30-1:30 p.m. Structures that Support Students' Identities in Informal Physics Programs

Contributed – Brean Elizabeth Prefontaine, Michigan State University, East Lansing, MI 48912-4147

Claudia Fracchiolla,Claire Mullen, Shane Bergin, University College Dublin

Kathleen Hinko, Michigan State University

Understanding how one builds a physics identity is an important step to creating structures and practices that support physics students both in and out of the classroom. We have investigated how university students' physics identities can be fostered through teaching youth in informal physics programs. We collected reflections and interviews from participants in three different informal programs and analyzed them with an operationalized Communities of Practice framework. Our analysis shows that students' identities can be supported through different structures and practices within each program. We find that students' personal values aligning with the program's mission was the biggest predictor of membership, while interactions with members of the community served as the most important mechanism for integration into the community. This work illuminates the specific aspects of informal physics programs that facilitate physics identity formation among the university students who choose to participate.

PAR-C.06: 12:30-1:30 p.m. Three Productive Ways Physics Students Utilize a Digital Learning Environment

Contributed – Elias Euler, Uppsala University, Upplands 751 20 Sweden

Christopher Prytz, Rudbeckianska gymnasiet

Bor Gregorcic, Uppsala University

In this paper, we present three types of activity that we have observed during students' self-directed use of a physics software called Algodoo. In contrast to many common digital learning environments used in physics education, Algodoo allows students to explore a variety of physics phenomena within the same digital learning environment. We describe the characteristics of the three activity types and discuss how the types can be seen as productive for the teaching and learning of physics. For the interested physics teacher and physics education researcher, we present how, in allowing students to creatively engage within physics environments such as Algodoo, physics educators can help students springboard into a range of relevant physics topics while supporting the students' agency and divergent thinking.

MONDAY

Session PAR-C.07 Science and Religion — Monday, July 19, 12:30–1:30 p.m.

Sponsor: Committee on History and Philosophy in Physics

PAR-C.07: 12:30-1:30 p.m. A Space Oddity: Exploring the Intersection of Science and Religion in Physics Classrooms

Contributed – Richard P. Hechter, University of Manitoba, Canada

Physics education, especially astronomy education, is an ideal place to explore the intersection of science and religion. Grounded in tenets of peace education, the study of astronomy can be enriched by punctuating learning outcomes of physics concepts with the stories, mythlore, and teachings emanating from religion and culture. The purpose of this approach is to advance the physics we are teaching by resonating with students' identities and being an entry to the greater conversation about (under)representation in physics, and how the intersection of religion and science provides insight into living and learning in a multi-religious and multicultural world. This session, which centers on the calendar by which cultural and religious observances are determined, advocates for integrating elements of cultural and religious knowledge with astronomy concepts as an inclusive space for all students. This pragmatic approach aligns with andragogical intentions of developing and delivering an increased holistic and inclusive curriculum.

PAR-C.07: 12:30-1:30 p.m. Activities to Address Equity and Injustice in Physics Classes

Contributed – Christopher Gosling, Saranac Lake High School, Saranac Lake, NY 12983

Natasha G. Holmes, Cornell University

The Underrepresentation Curriculum Project (URC) provides resources to help educators address equity and injustice in STEM through education. Several of the

URC lessons offer students the opportunity to gather information and create artifacts. We will briefly present relevant URC lessons and share artifacts that students created while completing these assignments. These artifacts are not only personally meaningful, but also serve as mechanisms to chronicle student learning around these challenging topics.

PAR-C.07: 12:30-1:30 p.m. Anomalies and Miracles: Revisitng an Undergraduate Science and Religion Course

Contributed – David L. Morgan, Richard Bland College, Chesterfield, VA 23834

Michael Pettinger

The presenters will describe a course that was developed to explore themes related to science and religion. The course — "Science and Religion: Anomalies and Miracles" — was team taught by professors of physics and religious studies, and was designed around a unifying question that motivated the course content and discussions: Historically, how have practitioners of science and religion dealt with unexplained or unexpected events? How do particular worldviews inform the way they receive, interpret, or reject novel ideas? We will present a big-picture overview of the course content, as well as some specific lessons and discussions that illustrate the unique approaches that the team-taught structure permitted. We will also discuss the results of a student survey about the course and explore what students described as the enduring understandings, more than ten years later, that they retained from the experience.

PAR-C.07: 12:30-1:30 p.m. Challenging Student Ideas About Religion in a General Education Course

Contributed – Mariel Meier, Oglethorpe University, Atlanta, GA 30319

COR-400, Science and Human Nature, is a general education science course required of all students at Oglethorpe University. In this course, students learn about scientific ways of knowing and the scientific process through the lens of scientific revolutions. Specifically, the course content focuses on the Copernican Revolution and the Quantum Revolution of the early 20th century. Students often enter this course with preconceived notions of the relationship between religion and the scientific community – in particular, they often perceive religious authority to have produced barriers to scientific progress and discovery throughout history. During this course, we investigate and challenge these notions. In this presentation I will discuss how this material is presented to students and highlight student comments that demonstrate their evolution in thinking about the relationship between science and religion.

PAR-C.07: 12:30-1:30 p.m. Critical Reflections on Sharing Stories from a Physics Community

Contributed – Robert P. Dalka, University of Maryland

Gathering and sharing personal stories is a science communication approach that communities have used to showcase the range of individuals who participate in their respective community. In this talk I will share my experiences as an undergraduate writing a column focused on one university's Physics community for the student newspaper. I originally treated this as a journalistic activity in which I interviewed a member of the community about a specific topic and presented my account of the conversation supplemented by outside resources. Now, as a graduate student, I am critically reflecting on the process of writing the columns. As I do this, I am finding lessons that can inform future projects that aim to share stories from community members. I will discuss the process of writing these columns and my current thoughts resulting from critical reflections, connecting this with work that others have done around representation in research communities.

PAR-C.07: 1:30-1:30 p.m. Implementing Positive Psychology in Teaching Physics

Contributed – Rahmat Rahmat, SCC Iowa, Burlington, IA 52655-1552

Sau Kuen Yam, SCC Iowa

Positive Psychology is the scientific study of the strengths that enable individuals and communities to thrive. The field is founded on the belief that people want to lead meaningful and fulfilling lives, to cultivate what is best within themselves, and to enhance their experiences of love, work, and play. Positive Psychology can be used to improve positive learning environment and promote active learning in physics. It can be useful to inspire physics students to have fun with science activities.

PAR-C.07: 12:30-1:30 p.m. Paris, Descartes, Newton, and the Void

Contributed – Bradley K. McCoy, Azusa Pacific University, Azusa, CA 91740

Reactions of religious organizations to the concept of vacuum (i.e. the void) changed drastically from the University of Paris condemnations in 1277 AD, to Descartes conception in The World (1664 AD), to Newton's description in Principia (1687 AD). This talk surveys the reactions to, and eventually reception of, the concept of vacuum on religious grounds.

PAR-C.07: 12:30-1:30 p.m.. The Effect of Spirituality and Religiousness on Physics Identity and Career Choice

Contributed – Saeed Moshfeghyeganeh, Florida International University, Miami, FL 33199

Zahra Hazari, Florida International University

A "conflict thesis", which claims a methodological, factual, and political conflict between science and religion [1], has led to stereotypes about the low competence of religious people in academic careers, especially in western contexts [2]. People with deeply held religious beliefs are aware of these negative stereotypes about them, which can lower their interest and performance in science [3]. In this study, we draw on survey data to examine the effect of spirituality and religious beliefs on physics identity and career choice.

PAR-C.07: 12:30-1:30 p.m. 1:30-2:30 p.m. The Influence of Christianity on 19th-Century Physicists

Contributed – Jill A. Macko, Eastern Nazarene College, Quincy, MA 02170-2999

The 19th-century was a period of giant leaps in physics. Young demonstrated the wave nature of light. Dalton developed atomic theory. Maxwell unified electricity and magnetism. The list goes on and on. At the end of the century, Lord Kelvin famously declared, "There is nothing new to be discovered in physics now." Each of these discoveries were performed by human beings, who were influenced by their educational background, family upbringing, religious beliefs, and more. For example, Young stated: "For the talents which God has not given me, I am not responsible, but those which I possess, I have hitherto cultivated and employed as diligently as my opportunities have allowed me to do." How did this belief in God's gifts of talent impact his scientific work? This talk will focus on the religious views of significant physicists of the 1800's. Particularly, we will examine how the Christian faith of many 19th-century physicists influenced their scientific endeavors and shaped the field of physics as we know it.

Session PAR-C.08 PER: Student and Instructor Support & Professional Development, Program and Institutional Change

Monday, July 20, 12:30–1:30 p.m. Sponsor: AAPT

PAR-C.08: 12:30-1:30 p.m. Coding Students' Statements of Science Degree and Transfer Self-Efficacy

Contributed – Laura A. H. Wood, Michigan State University, East Lansing, MI 48824

Angela J. Little, D'Mario Northington, Vashti Sawtelle, Michigan State University

Self-efficacy, or confidence in one's ability to perform some task, is often used as a predictor of academic persistence, particularly in science fields with low retention and in the difficult process of transferring from a two-year college (TYC) to a four-year college (FYC). Self-efficacy has traditionally been measured quantitatively through surveys explicitly asking for confidence rankings. We describe the process of developing a codebook to qualitatively code statements of self-efficacy made in open-ended settings like interviews. To develop this codebook, we used interview and written data from two populations: (1) FYC students pursuing a science degree; and (2) TYC students planning to transfer to a university. The discussion prompts were designed to elicit discussion of these students' self-efficacy to complete their degrees in natural science majors, to navigate academic requirements, and, when applicable, to transfer to a FYC. We will discuss the mechanics of using this codebook and intended applications.

PAR-C.08: 12:30-1:30 p.m. Co-Teaching an Introductory Mechanics Course; An Opportunity to Teach or Learn?

Contributed – Azita Seyed Fadaei, South Seattle Community College, Seattle, WA 98122

Elizabeth Schoen. South Seattle Community College

Classes with multiple teachers is a challenging way for teaching science. The hard part is, teachers have mostly chosen their teaching styles, and blending teaching styles after years of development can be daunting. This limits opportunities to try new approaches. However, co-teaching provides the opportunity to teach with different approaches and group work strategies, which can be a little hard but exciting. We decided to follow the same lesson plans, lab tools, quizzes and grading strategy for three introductory calculus-based mechanics classes for one quarter, including combining the classes in our Learning Management System, Canvas. We were all equally responsible as the course instructor in our in-class instruction and our online presence as well. In this experience, we improved our teaching and collaboration skills and students learned how to engage in co-taught a class with many students and multiple teachers.

PAR-C.08: 12:30-1:30 p.m. Facilitating Instructor Change in an ISLE-Based Course

Contributed – Joshua Rutberg, Rutgers University, New Brunswick, NJ 08901

Sheehan H, Ahmed, Diane Jammula, Rutgers University - Newark

Eugenia Etkina, Rutgers University Graduate School of Education

Teaching in an active, student-centered environment is very different from teaching in a traditional environment, requiring a different set of dispositions, knowledge and skills. This environment can be particularly challenging for new instructors with no classroom experience. During the 2019-2020 academic year, we reformed the introductory physics courses at Rutgers, Newark using the ISLE approach. The laboratory portion of this reform included eight instructors, including one ISLE expert and four graduate teaching assistants with no previous teaching experience. In this talk we will discuss the professional development conducted and the changes we observed in lab instruction that occurred during the fall semester. Specifically, we will present the observation protocols we used, our measurements of instructor improvement, and the relationship between the instructor scores and student learning and attitudes about experimental physics.

PAR-C.08: 112:30-1:30 p.m. ISLE-based Reforms in an Urban Public University

Contributed – Diane C. Jammula, Rutgers University, Newark, NJ 07102-1897

Sheehan H. Ahmed, Rutgers University-Newark

Joshua Rutberg, Eugenia Etkina, Rutgers University Graduate School of Education

This talk will describe the innovations that we made in our introductory physics courses at Rutgers, Newark (algebra-based and calculus-based) using the ISLE approach. In the spring of 2019 we ran two pilot sections of ISLE-based labs and in the fall of 2019 we implemented whole course reforms in two of our introductory courses with over 400 students. The reforms included revisions in student activities in all three parts of the courses - lectures (large room meetings), recitations (small room meetings) and laboratories. We provided professional development for the 12 instructors and 20 Learning Assistants teaching these courses in a pre-semester workshop and weekly preparation meetings. We will share the details of the changes that we made and the data that we collected using the E-CLASS survey and student evaluations. Rutgers, Newark is an urban public university. Our experience will be useful for those teaching in similar institutions.

PAR-C.08: 12:30-1:30 p.m. Periscope: Looking into Learning in Best Practices Physics Classrooms

Contributed – Rachel E. Scherr, University of Washington

Periscope is a set of lessons that connects big questions of physics teaching and learning to authentic video episodes from best-practices physics classrooms. Periscope lessons are useful if you supervise learning assistants or teaching assistants, lead faculty development, seek to improve teaching in your department, or want to improve your own teaching. Periscope's primary aim is to help STEM instructors see authentic teaching events the way an expert educator does – to develop their "professional vision" (C. Goodwin, American Anthropologist 96(3), 1994). This development of professional vision is particularly critical for educators in transformed STEM courses, who are expected to respond to students' ideas and interactions as they unfold moment to moment. By watching and discussing authentic teaching events, instructors enrich their experience with noticing and interpreting student behavior; practice applying lessons learned about teaching to actual teaching situations; train to listen to and watch students in their own classrooms by having them practice on video episodes of students in other classrooms; observe, discuss, and reflect on teaching situations similar to their own; develop pedagogical content knowledge; get a view of other institutions' transformed courses; and expand their vision of their own instructional improvement. Periscope is free to educators at physport.org/periscope.

PAR-C.08: 12:30-1:30 p.m. Research Results and Best Practices for GTA Preparation

Contributed – Emily Alicea-Munoz, Georgia Institute of Technology, Atlanta, GA 30322

Graduate teaching assistants (GTAs) are essential in the teaching of introductory physics at many universities, and have been so for over a century. However, no formal efforts to prepare GTAs for their teaching responsibilities existed before roughly 1970, and only the last three decades have seen systematic research on the best methods of GTA training. In this talk, I provide a brief summary of the most salient results from research in GTA preparation, and synthesize the most important recommendations from the literature into the six (plus one) principles for best practices in GTA development.

PAR-C.08: 12:30-1:30 p.m. Resonance: Peer Group Mentoring for First Year, Undergraduate Physics Majors

Contributed – Laura J. Tucker, Irvine, CA 92697-4575

Kameryn Denaro, University of California, Irvine

To address the challenge of involving physics majors into the department early in their career, we created a peer group mentoring program. Incoming undergraduate first-year students are assigned to a group of other incoming students and two undergraduate peer mentors. This mentoring circle meets multiple times per quarter to discuss common student concerns and success strategies. Initial outcomes include higher GPA for program participants, a difference that is not explained by demographic factors or incoming preparation.

MONDAY

PAR-C.08: 12:30-1:30 p.m. Scrutinize SA-Student Interaction in Inquiry-oriented College Physics Courses

Contributed – Jianlan Wang, Texas Tech University, Lubbock, TX 79409

Beth Thacker Kyle Wipfli, Stephanie Hart, Texas Tech University

Student assistants (SA), which includes graduate and undergraduate teaching/learning assistants, are pivotal to non-traditional physics instruction in large classrooms. Despite its effectiveness, little is known about how SA-student interactions promote students' learning. How should SAs respond to students' questions? What support should SAs provide or refrain? What makes a SA effective or ineffective? We are particularly interested in SAs' questioning skills. We propose a coding scheme to scrutinize SA-student interactions. For analysis, we segment a SA video into vignettes based on different situations SAs encounter and define activities like guiding questions, probing questions, and imparting information. From the pattern of activities, we code a vignette as one of the 6 levels on the hierarchy of students' accountability. The frequency of certain levels in multiple vignettes could suggest a SA's practical knowledge of questioning, which will be compared with SAs' narrated knowledge measured by a written test of their questioning skills.

PAR-C.08: 12:30-1:30 p.m. Studying Student Reasoning in an ISLE-based Classroom

Contributed – Sheehan H. Ahmed, Rutgers University - Newark, Newark, NJ 07102

Diane Jammula, Rutgers University - Newark

Joshua Rutberg, Eugenia Etkina Rutgers. University Graduate School of Education

In this talk we present data collected in two introductory physics courses (algebra-based and calculus-based) using the ISLE approach at Rutgers, Newark. The data come from students' solutions of traditional physics problems evaluated using a rubric that assesses student reasoning abilities, such as ability to communicate, to use different representations consistently, and to evaluate their answer. We track students through one semester and analyze their progress using weekly assessments and course exams.

Session PAR-C.09 Physics Education Research in Labs Monday, July 20, 12:30–1:30 p.m.

Sponsor: Committee on Research in Physics Education Co-Sponsor: Committee on Laboratories

MONDAY

PAR-C.09: 12:30-1:30 p.m. A New Advanced Lab Textbook, with Support for Remote Instruction

Contributed – Walter F. Smith, Haverford College, Haverford, PA 19041-1392

Melissa Eblen-Zayas, Carleton College

Kozminski Joseph, Lewis University

Jami Shepherd, Paul Freeman, University of Auckland

We have co-authored a new textbook, *Experimental Physics: Principles and Practice for the Laboratory*, inspired by the 2014 AAPT report "Recommendations for the Undergraduate Physics Laboratory Curriculum". We discuss the philosophy and organization of the book, and the support that will be offered for remote education, assuming it is needed this year. We also detail aspects that differ from previous texts. For example, ours is written by a team of 17 research-active authors, allowing authoritative writing about techniques relevant to all major areas of physics; detailed instructor manuals are included so that you can confidently teach outside your area of expertise. As of abstract submission, development of remote instruction materials is only beginning. They will include a variety of approaches, such as modifications of some experiments so they can be done at home using modestly priced kits, as well as "choose your own adventure"-style video walkthroughs of other experiments.

PAR-C.09: 12:30-1:30 p.m. Challenges and Opportunities for Innovation and Research in Physics Lab Education

Invited – Benjamin M. Zwickl, Rochester Institute of Technology, Rochester, NY 14623

I overview three aspects of physics lab instruction where there is a tremendous opportunity for education researchers and innovative practitioners to impact student learning. The first area is shifting the theory-centric culture of physics education to a balanced emphasis on experiment and theory, which reflects professional practice within physics. I will show why the laboratory should be recognized as a critical environment for learning complex problem-solving and as highly relevant for students' career preparation. The second area is embedding scientific practices within labs. Within the growing literature there is variation in viewing practices as discrete and transferrable skills versus integrated and highly contextualized, which has implications for researchers and educators. Third, I see potential for more project-based courses to blur the boundaries between lab instruction and research experiences by integrating a range of practices and reframing the purpose of a lab, which can affect students' autonomy and identity within the lab.

PAR-C.09: 12:30-1:30 p.m. Changes to Equipotential Diagrams to Improve Student Ranking of Electric Potential

Contributed – Raymond Zich, Illinois State University, Normal, IL 61790-0001

Rebecca Rosenblatt

Amber Sammons, Andrew Princer, Jeffrey Rosauer, Illinois State University

Student issues with both understanding electrical potential and difficulties with interpreting diagrams have been well explored. A major issue in student ranking of electric potentials is identification of the sign of the electric charge. An investigation of modifying traditional equipotential diagrams based on theories of visual affordances to improve students' recognition of electric change sign when ranking electric potential was undertaken. A prior study showed equipotential diagram modifications significantly increased student gaze times at the diagrams without increasing students' overall correctness rates. In this study modifications of color and line style were made to equipotential lines to increase visual salience of indicators of change sign. Students were randomly assigned to the traditional or modified diagrams and asked to compare electric potentials for indicated points on given diagrams. Pre- and post-test comparisons and the results of student interviews will be presented to clarify the specific issues students have reading equipotential diagrams.

PAR-C.09: 12:30-1:30 p.m. Exploring Student Use of "Goes Like" Thinking When Linearizing Data

Contributed – Charlotte Zimmerman, University of Washington University of Washington Seattle, WA 98105

Alexis Olsho, Andrew Boudreaux, Western Washington University

Suzanne White Brahmia, University of Washington

"Goes like" thinking refers to the way that physics experts quickly relate the behavior of one changing quantity to that of another, e.g., "the electric field goes like one over R squared.'" This statement is deeply meaningful and intuitive to experts, who understand why other quantities such as charge are omitted; however, it is not clear that students interpret this phrase the same way. One application of "goes like" reasoning is data linearization---choosing quantities to use for the independent and dependent axes to produce a linear graph whose slope has meaning. Preliminary work suggests that students may not understand the value and meaning of data linearization. We aim to describe our attempts to design and assess online lab curriculum in an introductory physics course addressing data linearization, and discuss some of the ways students make sense of their data analysis using "goes like" reasoning.

PAR-C.09: 12:30-1:30 p.m. Learning Outcomes in Simple Harmonic Motion Labs Aided by Simulations*

Contributed – Emily C. Allen, The Governor's Academy - Byfield, MA 01922

Sheila Sagear, Andrew Duffy, Manher Jariwala, Boston University

Computer simulations have been used to support student learning in physics to boost conceptual understanding and make labs more widely accessible. To better understand their impact on student learning outcomes, the use of HTML5-based computer simulations for topics in mechanics were investigated in a large, algebra-based, studio physics course for life science students at a private, research-intensive institution. For the past three years, we have used an A/B testing methodology to compare learning outcomes associated with a lab activity on simple harmonic motion. Different groups in this study included students using traditional hands-on equipment only, a simulation only, or, a hybrid combination of both. We will present our findings of this study in the context of previous work and discuss the larger implications of the use of simulations in physics education.

*Funded by NSF grant DUE 1712159

PAR-C.09: 12:30-1:30 p.m. MAPLE, the Modeling Assessment for Physics Laboratory Experiments

Contributed – Benjamin Pollard, University of Colorado Boulder, and JILA, Boulder, CO 80309

Laura Ríos, California Polytechnic State University, San Luis Obispo

Michael Fox, Alexandra Werth, H. J. Lewandowski, University of Colorado Boulder, and JILA

Physics laboratory classes offer great potential for learning, often in ways that are distinct and complementary to theory-focused courses. However, there are relatively few research-based assessments that are suitable for use in an upper-division physics laboratory course. Our group has created a new set of research-based assessments for measuring a central aspect of laboratory learning: modeling. The assessments, known as the Modeling Assessment for Physics Laboratory Experiments (MAPLE), are computer-based surveys with two parts. The first part is a "choose your own adventure," while the second part consists of standard coupled multiple response items. There are three surveys in MAPLE, each contextualizing modeling within different experimental apparatus: a pendulum, an op-amp circuit, and a laser incident on two polarizers. I present the development process and theoretical foundations of MAPLE, describe the assessments themselves, and discuss how they can be used to measure and improve laboratory learning.

PAR-C.09: 12:30-1:30 p.m. Re-defining Lab Norms via Professional Learning Communities: Instructors' Expectations

Contributed – Edit Yerushalmi, Weizmann Institute of Science, ISRAEL

Smadar Levy, Zehorit Kapach, Esther Magen, Weizmann Institute of Science

We present a study of a large-scale intervention designed to shift lab instruction away from "cookbook" lab norms. The intervention was implemented in a network of Professional Learning Communities of Israeli high-school physics teachers (N=250; ~20% of the national workforce), operating in a high-stakes exam setting, with limited resources, catering to diverse groups of students. An introductory questionnaire examined teachers' framing of the instructional lab norms as compared to an experimental research lab (via a modified E-CLASS), as well as the lab goals that the teachers valued. The questionnaire was an integral part of the teachers' learning process. The teachers acknowledged the disparity between their optimal lab goals and prevailing ones, in particular as concerns experimental design. We discuss the implications for the design of an intervention addressing both teachers' interest in change as well as the constraints imposed by the setting in which they work.

PAR-C.09: 12:30-1:30 p.m. Re-defining Lab Norms via Professional Learning Communities: Meeting the Constraints

Contributed – Smadar Levy, Weizmann Institute of Science, ISRAEL

Zehorit Kapach, Esther Magen, Edit Yerushalmi, Weizmann Institute of Science

We present a study of a large-scale intervention designed to shift lab instruction away from "cookbook" lab norms. The intervention was implemented in a network of Professional Learning Communities of Israeli high-school physics teachers (N=250; ~20% of the national workforce). The intervention was tailored to respond to findings on teachers' dissatisfaction with the limited scope of experimental design employed in traditional labs, as well as the highly constrained setting in which these teachers work: a high-stakes exam setting, limited resources, and diverse groups of students. The intervention followed two design guidelines: a) restructuring traditional labs, by encouraging students to reflect on the considerations underlying the experimental design; b) an evidence-based learning process involving teachers in collaborative reflection on classroom enactments of the restructured labs. We found that most teachers chose to carry out the restructured labs, even though they expressed concerns about the demands, as compared to the standardized exams.

Session PAR-C.10 Remote Delivery of High School Labs: Use of Existing Teaching Resources

Monday, July 20, 12:30–1:30 p.m. Sponsor: AAPT

PAR-C.10: 12:30-1:30 p.m. Development of Physics-I (Kinematics) Lab-class for Virtual (fully online) Delivery

Contributed – Neel Haldolaarachchige, Bergen Community College, Paramus, NJ 07652

Kalani Hettiarachchilage, Seton Hall University

First, a fully comprehensive lab-manual for physics-I (kinematics) online-class was developed by using video-analysis and simulations. Only open educational resources (OER) were used to develop the lab manual. New lab manuals for ten experiments were written to investigate important basic concepts of kinematics class. Online lab classes are done synchronous format (at regular meeting time) online-live. During online meetings, the instructor work on at least two shared windows simultaneously one for writing and explanation (use the tablet mode of a dual-mode laptop) and one to access the lab manual. The instructor works with the students to collect the data by using virtual tools and demonstrate further data analysis, graphing, curve-fitting, calculations, and error analysis with the MS-Excel software package. Finally, students were required to compile a full lab report at a scientific standard and submitted to the learning-management-system (LMS) via plagiarism-checker. The learning outcome was analyzed by quizzes and exams.

PAR-C.10: 12:30-1:30 p.m. Hands On Minds On Engagement through Remote Learning

Contributedm – Lynn Jorgensen, Gilbert High School, Mesa, AZ 85209

In this new realm of remote learning, many of us are looking for ways to continue the Hands-on portion of the Hands-on Minds-on approach to learning and instructing. With my high school physics class, I chose to work on an optics unit. Optics lends itself nicely to the remote learning platform since most every student has the same basic supplies at home needed for the activities. We give very basic instructions on the activity, mostly HOW to build, or set up the demonstration. In this webinar we will go over the process of what to do with the data students collect. How to use the remote learning format to then discuss the relevant physics principles. And how to augment the at home activities with simulations and worksheets for practice of concepts.

PAR-C.10: 12:30-1:30 p.m. Introducing Current Research to Students Utilizing BiteScis Lessons Remotely

Contributed – Shannon Morey, Abbott Lawrence Academy, Lawrence, MA 01843

Stephanie Keep, BiteScis

Kelsey Lucas, University of Michigan

BiteScis (bitescis.org) is dedicated to engaging students by exposing them to current science research that provides context to the content they are expected to master. BiteScis lessons are developed in collaborative partnerships between high school teachers and early career STEM researchers and most are well suited to remote learning. The development process provides relevant, useful, and unique professional development for both "BiteScientist" partners. The lessons that result are standards-aligned, easy-to-implement, and are designed to root out misconceptions. This presentation will describe BiteScis' physics resources that translate well to remote learning and explain a variety of ways teachers have and can continue to use BiteScis lessons to teach remotely.

PAR-C.10: 12:30-1:30 p.m. Phone Physics: Using Cell Phone Sensors for Distance Learning Experimentation

Contributed – Susan M. Johnston, Livermore High School, Livermore, CA 94550

Amanda C. Johnston, Purdue University

Smartphones have the potential to revolutionize how students learn physics. This talk will introduce teachers to several hands-on activities designed to explore core disciplinary ideas in physics. The activities exploit the highly sensitive and precise sensors in the smartphones that students already own, and of which they are expert users. You will be amazed at the performance of the sensors and the diverse set of high-precision experiments that are now possible. These activities are designed to require minimal additional equipment beyond the smartphone, allowing them to be conducted in classrooms with limited resources and through distance learning programs to engage in sophisticated experimental activities at home. Several of the activities will be presented and resources to perform others will be provided. Examples include activities on motion, collisions, energy, and magnetic fields of the Earth.

This work has been developed in collaboration with Dr. David Rakestraw from the Lawerence Livermore National Laboratory (LLNL) as part of the LLNL Teacher Research Academy.

PAR-C.10: 12:30-1:30 p.m. Physics at Home Project: A COVID-19 Necessitated Assignment

Contributed – Philomena N. Agu, Barbara Jordan High School, Houston, TX 77026

My students are used to learning physics through laboratory experiments, demonstrations, and projects. To simulate similar hands-on learning experience in a virtual classroom and make the subject more relevant, the students completed "Physics At Home Project". They performed two physics experiments or demonstrations at home, took pictures of five things related to physics, explained how the pictures depicted physics concepts and principles, created video and QR code of their work, and presented the project via Teams, an online platform. The outcome were varieties of physics topics including, forces, Newton's laws, heat transfer, specific heat, energy conservation, impulse-momentum theorem, and collision. During the presentation, the students were able to use physics vocabulary terms to discuss their project. They discovered relevance in some materials learned in physics by observing that everyday things in their environment are related to physics. Also, they learned how to present work in an online platform, and make YouTube video and QR code.

PAR-C.10: 12:30-1:30 p.m. QuarkNet Creates a Big Online Physics Event (twice)

Contributed – Kenneth Cecire, University of Notre Dame, Department of Physics, South Bend, IN 46616

Each year, International Masterclasses (IMC) bring authentic particle physics data analysis to high school students and teachers. We had just started for 2020 when the pandemic came. By mid-March all IMC videoconferences were canceled, thus ending masterclasses for thousands worldwide. A group in QuarkNet responded by building and facilitating a masterclass to be done on a large scale with a core analysis that students could perform remotely with coaching by their teachers and online support from staff. We called it the Big Analysis of Muons in CMS (BAMC). Two rounds of BAMC were accomplished: one in April with students of mostly QuarkNet teachers and an international round in May. Between them, an estimated 700 students participated from around the world.

PAR-C.10: 12:30-1:30 p.m. QuarkNet Supports Remote Analyses of Cosmic Rays for High Schools

Contributed – Deborah Roudebush, QuarkNet, Fairfax, VA 22033

Mark Adams, QuarkNet at Fermilab

QuarkNet High School students and teachers have collected data on cosmic ray muons. Their data is available to all on the i2u2.org site. QuarkNet has made available several experimental analysis tools to use with the existing 100K data files. In a remote learning environment, students can design their own experiment to measure fundamental properties like the speed or lifetime of muons, changes in the cosmic ray rate over time or with angle of orientation, or investigate the size of cosmic ray air showers.

PAR-C.10: 12:30-1:30 p.m. Using Cellphone Sensors for Data Collection

Contributed – Joseph L. Zawicki, SUNY Buffalo State, College Science & Math Buffalo, NY 14222

David Abbott, Dan MacIsaac, Brad Gearhartm SUNY Buffalo State College

Kathleen Falconer, University of Cologne

The recent pandemic has severely restricted in-person instruction in K-16 settings. A recently developed set of tools, PhyPhox*, created in Germany, allow learners to harvest data directly using their cell phone. Experiments currently under development across a number of topics from mechanics ((In)elastic collisions, acceleration, pendulum motion) to audio analysis (Doppler effect, sonar, speed of sound) and creatively utilize multiple sensors to collect raw data. This free tool is available online and works across multiple cell phone platforms and services. Physics educators in RWTH Aachen University initially developed the tool and have collaborated with physics educators in New York State to develop and validate deployment strategies, including the use of instructional scaffolding approaches, video conferencing tools (including the use of breakout rooms for lab groups) and other appropriate techniques.

*The program may be downloaded and additional resources may be found at: https://phyphox.org/.

PAR-C.10: 12:30-1:30 p.m. Video-based Grapical Analysis Problems

Contributed – Cindy Schwarz, Vassar College, Poughkeepsie, NY 12604

Saumya Arya, Vassar College

We are finishing development of around 20 video-based activities for topics in mechanics at the introductory undergraduate level (also useful for high school physics and AP physics I). Videos were taken of real moving objects - like a basketball, a girl on a playground slide, a billiard ball collision, a girl on a swing, and even a diving board undergoing damped oscillatory motion to name a few. Videos were analyzed using Logger Pro. Each activity has the actual video, tracked motion images, graphs of relevant quantities and physics concept questions that rely primarily on getting information from the graphs. These will be integrated into the Expert TA system before the start of the fall semester. They can be used for homework where students will gain skills in estimating and interpreting graphs. They can also be used to replace some lab experiences students might miss because of online teaching.

Session PAR-C.11 Tools for Data Analysis Monday, July 20, 12:30–1:30 p.m.

Sponsor: Committee on Physics in Undergraduate Education Co-Sponsor: Committee on Laboratories

PAR-C.11: 12:30-1:30 p.m. Computation and Experimentation as Equal Partners in Undergraduate Lab Education

Invited – Martha-Elizabeth Baylor, Carleton College, Department of Physics and Astronomy, Northfield, MN 55057

Jay D. Tasson, Carleton College

In the undergraduate lab experience, computation and experimentation are typically presented as distinct lab experiences. This approach ignores the important interplay that can exist between these two different ways of understanding the physical world. At Carleton College, we developed one two-week lab that treats computation and experimentation as interconnected, equal partners in students' understanding of the natural world. I will discuss this lab that focuses on finding the half-lives of two simultaneously decaying isotopes and discuss how we encourage students to think about the interplay between computation and experimentation. Additionally, I will discuss efforts to promote lab skill development and inclusion broadly in this sophomore-level lab course and particularly how these inclusion efforts are manifested in the lab I will present in this talk.

PAR-C.11: 12:30-1:30 p.m. Developing Data Analysis Skills with Simple, Common Experiments

Invited – Paul C. Arpin, California State University, Chico, Chico, CA 95929-0202

In our Advanced Laboratory course students develop practical data analysis skills working through two simple experiments early in the semester that we then revisit throughout the course. For most of the semester, students rotate through different experiments. Having these two common experiments enables all students to practice specific data analysis and error analysis techniques on their own measured data at appropriate times during the semester. For example, students calculate the wavelength of a laser from the glancing incidence diffraction pattern from a machinist's ruler. They gradually refine the estimates of the wavelength and the corresponding uncertainty. In this talk, I will describe the two experiments and how we use them to teach data analysis and error analysis throughout the semester.

PAR-C.11: 12:30-1:30 p.m. Enhancing Computational Instruction for Physics Majors: Developing Tools for Assessment

Invited – Kendra Letchworth-Weaver, James Madison University, Harrisonburg, VA 22807

Harold Butner, Keigo Fukumura, Gabriel Niculescu, Klebert Feitosa, James Madison University

Computer programming is an essential skill for physics majors seeking employment in a highly technological world. The advent of "big data" in business, engineering, and traditional STEM fields requires graduates proficient in data acquisition, storage, manipulation, and analysis. Physics departments are responding to this trend by integrating computational instruction into their undergraduate programs, but questions remain regarding the effectiveness of this training. In the Department of Physics and Astronomy at James Madison University, we have developed a set of learning objectives related to computational skills and integrated these objectives throughout our curriculum, primarily in laboratory courses. Our team has also developed an assessment tool, consisting of multiple choice and free response questions, that can quantitatively measure students' computational skills within the context of physics. This presentation will discuss both the successes and challenges we encountered as we seek to enhance computational instruction and evaluate student learning improvement in our department.

Session PAR-D.01 Astronomy Paper

Monday, July 20, 2:30–3:30 p.m. Sponsor: AAPT

PAR-D.01: 2:30-3:30 p.m. A Flat Earth?

Contributed – Bruce Sherwood, University of North Texas, Argyle, TX 76226-2113

Flat-earthism is one kind of science denial, and it asserts that scientists conspire with governments to keep secret the "fact" that the Earth is flat. Many scientists' attempts to disprove a flat Earth unfortunately cite evidence that is not easily accessible to a non-scientist. I have made a navigable 3D computational model of a popular U.S. flat-earthers' model of a flat Earth, which makes it possible to identify a number of naked-eye observations that strongly disagree with the predictions of the flat-earthers' own model. This is potentially useful because flat-earthers privilege naked-eye observations as the only valid kind of evidence. I will demonstrate the computational model, which is available at tinyurl.com/FEmodel.

PAR-D.01: 2:30-3:30 p.m. Extending Engagement Beyond the Planetarium Show: Big Astronomy in Chile

Contributed – Jesica L. Trucks, Abrams Planetarium/Michigan State University, East Lansing, MI 48823

Kathleen Hinko, Michigan State University

Shannon Schmoll, Abrams Planetarium/Michigan State University

The Big Astronomy Project is a multi-institutional effort that aims to share the stories of the people and places that make big astronomy possible in Chile. We have developed a model, the Dome+ model, to identify best practices for extending engagement beyond planetarium shows. The model's main component is a planetarium show, where planetarium visitors are shown NSF ground-based observatories in Chile. To support STEM identity, interest, and agency for planetarium visitors, we are creating additional resources such as weekly virtual sessions with STEM professionals, a web portal with additional content, and a suite of hands-on activities. The project strives to 1) promote awareness of the investments in astronomy being made by the US in Chile, 2) encourage interest in diverse STEM career opportunities at large observatories, 3) share knowledge of the science enabled by big astronomy, 4) increase perceptions by Latinx youth and adults about careers at observatories.

PAR-D.01: 2:30-3:30 p.m. Extent of Formative Assessment-based Active Learning in Interactive Planetarium Shows

Contributed – Sara K. Schultz, Minnesota State University

Timothy F. Slater, University of Wyoming

Simply having a virtual reality planetarium facility to immerse students beneath a projected night sky in and of itself is insufficient to automatically ensure student learning occurs. Modern teaching strategies, like active learning, have consistently shown to move students toward a better and longer-lasting understanding in classrooms, and one naturally wonders how this plays out in the planetarium. This observation study evaluated the nature of active learning-based formative assessment conversation cycles in the planetarium and, using follow up clinical interviews, identified rationale or barriers to their use. A synthesis of collected data found scant evidence of complete formative assessment conversation cycles, but varying degrees of interactivity between the planetarium lecturer and the audience were observed. Similar to what researchers report about typical K-12 classrooms, the results of this study reveal that active learning featuring assessment conversation cycles is largely absent in the planetarium programs sampled.

MONDAY

PAR-D.01: 2:30-3:30 p.m. Hands-on Radio Astronomy in the Classroom Using a Horn Telescope

Contributed – John Makous, Providence Day School, Charlotte, NC 28270

The description and operation of a horn radio telescope that can be used in introductory physics and astronomy classrooms will be presented. The telescope used in the investigations, which is designed to detect the 21 cm wavelength emitted by atomic hydrogen, can be constructed easily and at an affordable cost. Projects that will be discussed include making a map of hydrogen in the Milky Way Galaxy, measuring its profile, and determining a rotation curve.

PAR-D.01: 2:30-3:30 p.m. Online Astronomy Programming and Virtual Interaction

Contributed – Ken Brandt, Robeson Planetarium and Science Center, Mills, NC 8358

Using Zoom, Stellarium Planetarium Software, and video programming from NASA and ESA, I have built a set of planetarium programs being offered locally and internationally. Here I present lessons learned from these interactive programs, and a set of best practices for teaching astronomical content virtually. A major challenge has been audience interaction. I present some strategies to get the audience more engaged, as this might be useful anywhere virtual teaching and learning are being used.

PAR-D.01: 2:30-3:30 p.m. Preliminary Results on Students in Dispersed Remote Telescope Observing Teams

Contributed – Timothy F. Slater, University of Wyoming, Laramie, WY 82071

Brian Uzpen, Laramie County Community College

Undergraduate research experiences provide mechanisms for enculturating students into the community of scientific research and sharpening research skills. These experiences typically fall into two categories in astronomy: either highly competitive national experiences or localized experiences run by local faculty with access to institutional observing facilities. In leveraging opportunities provided by the remotely controlled Las Cumbres Observatory, we are exploring a third option—25 geographically distributed research teams of a mentoring faculty member and 3-to-4 undergraduate teams collaboratively measuring the distance to a nearby galaxy. As a first step to understanding potential impacts, we find limited changes to student perceptions of science identity, scientific community values and changes of their understanding of scientific inquiry, despite completing an entire inquiry cycle, including publishing of a formal scientific paper.

PAR-D.01: 2:30-3:30 p.m. Supporting Families' Collaborative Learning of Astronomy

Contributed – Luke D. Conlin, Salem State University, Salem, MA 01970

Megan R. Luce, Independent Consultant

At public observatories, families have an opportunity to learn astronomy together. However, the way public observations are typically structured present obstacles for collaborative learning. Often, only one person can look at a time while an expert describes what is in view and gives background information. We have been exploring ways of setting up activities for families to learn astronomy in more collaborative ways that rely less on facilitator explanation. We report on a study in which a family pilot tested new activities to encourage more collaborative sensemaking. We found key factors that supported the family's collaborative learning include (1) using activities that shift authority and control to each member of the family, (2) Having a variety of activities that can be deployed at strategic times rather than a fixed schedule, and (3) Being responsive to the family dynamics, including the emotional needs of each family member.

Session PAR-D.02 Effective Practices in Educational Technology

Monday, July 20, 2:30–3:30 p.m. Sponsor: Committee on Educational Technologies

PAR-D.02: 2:30-3:30 p.m. A Description of a Project-based Media Course for Pre-service Teachers

Contributed – Kathleen Ann Falconer, Universität zu Köln

Stefan Hoffmann, André Bresges, Universität zu Köln

Dan MacIsaac, Buffalo State College

We will describe a Project Based Learning course for physics pre-service teachers for the creation of STEM media. The Media Practicum (MP) course is split into two sections. The first section of MP is designed to help the pre-service teachers to develop an understanding of various tools, techniques and methods for creating media and using media and other educational technology in the school classroom. In groups, the pre-service teachers select a theme or concept which they then use as an exemplar for the use of the various tools, techniques and methods. The purpose of this first section of MP is to provide an opportunity for the students to make an informed decision about tools to use in their design and implementation of their media. The second section of the MP course is the creation of the media and documentation including the embedding of the media in an instructional context.

PAR-D.02: 2:30-3:30 p.m. Developing and Testing a New Educational App About Electric Fields

Contributed – Liana Rodelli, Ithaca College, Marlboro, NY 12542-6187

Colleen L. Countryman, Ithaca College

The physics education and computer science researchers at Ithaca College collaborated to develop a mobile application to provide students with a dynamic experience studying electric fields, a notoriously difficult topic. This study is the first in a longitudinal study comparing the impacts of the mobile application and paired worksheet activity to other learning tools including a laptop simulation and a worksheet-only activity. Participants include health science majors enrolled in an algebra-based physics class. The normalized gain in performance on a diagnostic administered prior to and after interacting with one of the three activities was used to measure the impact of each activity on student understanding. Student attitude was measured using a questionnaire in the post-activity diagnostic. The results show students prefer laptop activities as physics learning aids and students in the two sections, mobile application and laptop simulation, produced higher average gains in learning than those in the worksheet-only section.

PAR-D.02: 2:30-3:30 p.m. Dynamic Simulation to Help With the Understanding of Electric Fields

Contributed – Ted K. Mburu, Ithaca College, Rochester, NY 14618

Colleen Countryman, Ithaca College

Because electric fields cannot be touched or seen, simulations are often utilized to build students' understanding of them by providing them with a visual experience of electric fields and the motion of test charges through them. The objective of the simulation is to improve students' qualitative understanding of how electric fields are impacted by the charges around them by creating a dynamic representation of the electric field lines, field vectors, equipotential lines, and the voltage created by the charges on screen. After creating a charge configuration, students can observe the motion of test charges through the electric field. The simulation was built in JavaScript so it will run on most browsers on a computer or mobile device. The simulation is intended to be used by college students taking introductory physics courses. A study of the impact on students' understanding and attitude will be analyzed in future work.

PAR-D.02: 2:30-3:30 p.m. Effective Technological Methods and Teaching Practices Adopted to Successfully Complete the Calculus-based Physics II Course in Remote Method

Contributed – Pratheesh Kumar Jakkala, University of Cincinnati, OH 45221

This paper describes the technological methods adopted and implemented for the successful completion of the College Physics II course, after a sudden transition to remote teaching from face-to-face classes at a large University. This paper describes how the echo 360 learning capture system adopted for successful synchronous lecture delivery without changing the original class structure. Active student-engagement methods,in-class problem solving, peer-to-peer discussion methods, and support systems during live lectures are discussed. Assignment submission, conducting successful online exams, and effective grading practices are also discussed. Virtual office hours, accessing archived lectures and quick response time methods are discussed. A total of 225 students enrolled in the class, an average 80% live attendance, and 40.4 views per archived lecture are recorded. 91% of the students either agreed or strongly agreed that the transition went very smoothly and 96% of the students expressed their happiness with the overall learning experience using the newly adopted methods.

PAR-D.02: 2:30-3:30 p.m. Engaging Physics Students with Quizizz

Contributed – Patrice Noel Edwards, College Coastal Georgia, Brunswick, GA 31520

Many studies have shown that engaging students in the learning process increases their attention and focus, motivates them to practice higher level critical thinking skills, and promotes meaningful learning experiences. In this talk, I will share a way that I engage the students in the classroom setting and with online instruction using free a online tool called Quizziz. Quizizz is a free tool. It works on almost any device or web browser. You can access hundreds of learning quizzes that other instructors have created or you can create your own. This is a great way to promote student engagement and fun competitive learning especially when teaching online.

PAR-D.02: 2:30-3:30 p.m. Implementing Smartpens to Improve Rapid Feedback in a Physics Classroom

Contributed – Yuri B. Piedrahita, Purdue University, Lafayette, IN 47906

N. Sanjay Rebello, Purdue University

Feedback is an essential element of formative assessment, which has been highlighted among the fundamental techniques to achieve the National Science Education Standards. Rapid feedback aims to scaffold students' learning in the shortest amount of time possible; however, it is something difficult to accomplish in first-year introductory physics courses due to the usual large class size. The use of technology can ameliorate such limitations, becoming an alternative to offer students suitable and timely feedback in their learning process. This work implemented the use of smartpens to identify students' struggles in real-time with problem-solving within a physics recitation for engineering students. The use of smartpens allows students to solve problems on paper handouts, which is typical of recitations, while simultaneously monitoring student performance electronically using tablet-PCs, resulting in timely and more effective feedback from facilitators.

PAR-D.02: 2:30-3:30 p.m. New York Times Warm Earth Physics Applications 2008-2020

Contributed – John P. Cise, Austin Community College, Austin, TX 78701

For 12 years I have been using NYTimes articles on Global Warming to assist teaching fluids and heat concepts. NYTimes articles are pasted into word and edited to fit one page. Added are: graphics,introduction,questions,hints and answers to the standard printable word page. This presentation is at: http://CisePhysics.homestead.com/files/NYTOceanWarmingAAPTs2020.pdf 1000 NYTimes Physics concept applications are located at AAPT's ComPADRE site at: http://CisePhysics.homestead.com/files/NYTCisePhysics.pdf This physics and physical science resource site is listed at AAPT's ComPADRE and the AAPT's Physical Science Resource Center.

PAR-D.02: 2:30-3:30 p.m. QuarkNet Wednesday Webinars

Contributed – Spencer L. Pasero, Fermi National Accelerator Laboratory, Batavia, IL 60510

In recognition of the need for additional opportunities for remote learning for teachers and students, QuarkNet established the QuarkNet Wednesday Webinar Series, a set of five talks from physicists and educators offered via Zoom webinar through May and early June. We will discuss our experience coordinating and moderating these sessions and share lessons learned.

PAR-D.02: 2:30-3:30 p.m. Teaching a Blended Course with TopHat*

Contributed – Andrew G. Duffy, Boston University, Boston, MA 02215

TopHat is a platform known for in-class quizzing, with students using their phones to respond to questions. However, in our two-semester introductory algebra-based physics sequence, we are leveraging the TopHat platform to do significantly more than that. In addition to the in-class clicker feature, we are using TopHat for (1) pre-class preparation, with quizzes that include videos, content, and feedback from the students to the instructor; (2) online homework; (3) quizzes that are automatically graded; (4) an interactive e-book, with a significant number of embedded simulations. In this talk, I will provide some details about these four different uses, and show examples of each. The vast majority of the material we use was created by us, with a goal of making high-quality content available to the students for a reasonable cost.

*Funded by NSF grant DUE 1712159.

PAR-D.02: 2:30-3:30 p.m. The Spectrum Laboratory: An Online Learning Environment for Authentic Inquiry*

Contributed – Mary E. Dussault, Center for Astrophysics | Harvard & Smithsonian, Cambridge, MA 02138

With funding from NSF's DRK-12 program, the Center for Astrophysics | Harvard & Smithsonian is researching and developing a next generation browser-based spectra visualization and analysis tool, The Spectrum Laboratory: Investigating the World of Color. Accompanying curriculum investigations enable students to use spectra from publicly available research databases -from atoms and molecules, to plants and pigments, to stars, galaxies and exoplanets - to support a wide range of authentic inquiry projects in the classroom. Spectroscopy is the universal analytical tool of science, yet it is typically touched on only briefly if at all in most people's pre-college experience. Through this project we are testing the hypothesis that repeated opportunities to generate and analyze graphical spectrum plots and data, in association with real-world data and inquiry-based tasks, can help learners productively reorganize and prioritize existing ideas about light and color phenomena, and support them in productive participation in scientific practices.

*This material is based upon work supported by the National Science Foundation under Grant No. 1814077

PAR-D.02: 2:30-3:30 p.m. Utilizing Peer-Instruction and Metacognition on Quizzes to Improve Concept Learning

Contributed – Jessica E. Bickel, Cleveland State University, Cleveland, OH 44115

Leah Bunnell, Thijs Heus, Cleveland State University

This work examines peer-quizzing with metacognition in calculus based introductory physics. Students take individual quizzes and then redo part of the quiz with a partner. Because the students to choose which problems to redo, they must reflect on their confidence level on different concepts (questions). The results show there is a clear benefit to introducing weekly quizzes. While peer quizzes do not result in a clear improvement in the final concept assessment score, there is improvement in the normalized gain. Further, there is a clear signal that students who score above average on their quiz redos will also show above average assessment gains. These results show that while the intervention does not improve the overall grade, it helps individual students at all grade levels improve their understanding in relationship to their peers. It also suggests that interventions for students with low redo scores will have significant impact.

Session PAR-D.03 Exploring the Implementation of the NGSS Framework in Undergraduate Science Disciplines

Monday, July 20, 2:30–3:30 p.m. Sponsor: Committee on Research in Physics Education

PAR-D.03: 2:30-3:30 p.m. 3DL4US Project: Characterizing NGSS 3-Dimensionality in College Instruction

Contributed – Paul Bergeron, Michigan State University, East Lansing, MI 48824

Paul Nelson, Michigan State University

James Laverty, Kansas State University

The Next Generation Science Standards (NGSS) has called for a reshaping of science curricula to mirror the 3 Dimensions that define expert knowledge organization: Scientific Practices, Disciplinary Core Ideas, and Crosscutting Concepts. Conceived for the K-12 educational context, the philosophy of centering instruction around not just content knowledge but also the skills for engaging in science is equally amenable to college instruction. In order to characterize the extent of alignment between instruction and the NGSS, we have developed the 3 Dimensional Learning Observation Protocol (3D-LOP). In this talk, I will present results from our gateway science transformation project characterized by the 3DLOP. I will also discuss the impact of transforming assessment items to align with a 3D framework on efforts to likewise transform the instructional environment.

PAR-D.03: 2:30-3:30 p.m. 3DL4US Project: Examining College Assessments in the Age of NGSS

Contributed – James T. Laverty, Kansas State University, Manhattan, KS 66502

The Next Generation Science Standards have elevated doing science to the same level of importance as knowing science. Three-Dimensional Learning, on which the NGSS is based, is shifting the way we think about what we want students to learn. This change in learning objectives pushes us to think differently about what we assess: It's not just what students know, but also what they can do with their knowledge. We have developed the Three-Dimensional Learning Assessment Protocol (3D-LAP), which can be used to characterize assessments as aligning (or not) with scientific practices, crosscutting concepts, and core ideas; or to develop assessment tasks that align with these three dimensions. In this talk, I will demonstrate these uses of the 3D-LAP and show results from our larger transformation project using the protocol.

PAR-D.03: 2:30-3:30 p.m. 3DL4US Project: Implementation Hinges on Scientific Practices

Contributed – Paul Nelson, Michigan State University, Grand Rapids, MI 49506

Paul Bergeron, James Laverty, Kansas State University

Undergraduate science instructors typically have a diverse array of responsibilities, often complicated by mixed messaging surrounding the value and importance of teaching. If we hope to take Three-Dimensional Learning (3DL) to scale at the college level across institutions, disciplines, and content levels, it is critical that we develop and curate ways to reduce the perceived cost associated with such a transformation for these instructors. Based on analyses of large samples of assessments and instructional observations from introductory level chemistry, biology, and physics courses, we identify the Scientific Practice (SP) dimension as the key lever to initiating successful 3DL implementation. This message can be further streamlined with a conventional backward mapping lens to potential adopters: start by modifying existing assessment items to engage students in one of the SPs. Instructional adjustments will necessarily follow to support students' success in the class.

PAR-D.03: 2:30-3:30 p.m. Integrating the Three Dimensions of the NGSS into Rubric Design

Invited – Carla M. Evans, Center for Assessment, Dover, NH

The Next Generation Science Standards (NGSS) are comprised of three dimensions—disciplinary core ideas, science/engineering practices, and cross cutting concepts. The multi-dimensionality of the learning targets poses interesting challenges for performance task rubric design. The purpose of this presentation is to discuss considerations for integrating the three dimensions of the NGSS into rubric design. Draft grade span generic rubrics that integrate the dimensions will be shared.

PAR-D.03: 2:30-3:30 p.m. Bridging Skill Development from NGSS to the AAPT Laboratory Recommendations

Contributed – Joseph F. Kozminski, Lewis University, Physics Department, Romeoville, IL 60446-2200

The Next Generation Science Standards (NGSS) define a set of Science and Engineering Practices, which map well to the focus areas of the "AAPT Recommendations on the Undergraduate Laboratory Curriculum." Both of these promote development of skills and competencies critical for the research environment and employment in a range of job sectors, and, together, they provide a way to bridge scientific and engineering practices from K-16. This talk will give an overview of and mapping between the NGSS and AAPT Lab Recommendations and will discuss how skill development can be scaffolded from the NGSS high school curriculum through the undergraduate curriculum.

PAR-D.03: 2:30-3:30 p.m. Building Effective and Engaging Courses Supported by Evidence and Theory*

Invited – Michael Klymkowsky, University of Colorado Boulder, Boulder, CO 80303-4701

Melanie M. Cooper, Michigan State University

While we might assume that courses are intelligently designed to reflect core concepts and how people learn, all too often course materials reflect disengaged and encyclopedic surveys. Beginning with a fortuitous discussion on the energetics of chemical bonding, Melanie Cooper (Michigan State University) and I have worked to reframe the disciplinary purpose, driving narrative, and conceptual focus of introductory courses in general (CLUE) and organic (OCLUE) chemistry and biology (biofundamentals™). These efforts align with the NAS Framework for Science Education and are based on OER books supporting interactive courses that employ the beSocratic™ web-based system free-form formative assessment system. The result is an emphasis on helping students identify and apply the underlying processes that govern the behavior of the systems under study, enabling them develop well reasoned and plausible models for complex phenomena. Studies on learning outcomes reveal significant improvements in understanding of core ideas.

*Our work has been supported by a number of grants from the NSF as well as departmental and institutional support. sponsor: Jason May

PAR-D.03: 2:30-3:30 p.m. Psst! Did You Hear About this Course We're Taking?

Contributed – Jon Gaffney, Utica College, Utica, NY 13502

One of my favorite first day activities is to ask students to share rumors that they heard about the course, instructor, or Physics in general. After some general awkwardness and reassurance, students begin to open up about familiar fears such as heavy workloads, harsh grading, and very abstract concepts. But they may also attempt humor and playfulness, providing a unique opportunity to build community and paint the instructor's role as a coordinator rather than an authoritarian voice in the classroom. Soliciting rumors can help the instructor explain course policies and expectations with an accessible tone that helps to break down barriers in the classroom. Some caution needs to be taken when using this activity because it opens the instructors up to criticism and makes them vulnerable (but is that so bad?). This activity was initially designed by Robert Beichner.

PAR-D.03: 2:30-3:30 p.m. Using the NGSS Model of Energy in University Courses

Invited – Kara E. Gray, Seattle Pacific University, Seattle, WA 98119

Lane Seeley, Seattle Pacific University

The NGSS presents teachers and researchers with an opportunity to rethink both the model of energy that is taught and the way that energy is taught in K12 classrooms, as evidenced by the inclusion of energy as both a CCC and a DCI and by the emphasis placed on model building and argumentation in the science practices. We have also taken this as an opportunity to re-envision our energy teaching in our university courses. As a result, we've designed courses that allow students to construct a model of energy from real-world scenarios. This process stresses the use of multiple representations to facilitate student thinking including: energy theater, energy cubes, and energy diagrams. In some of our courses students are encouraged to develop their own energy diagrams. This talk will present a framework for a scenario-based energy unit and suggest strategies for supporting students in developing their own energy diagrams.

PAR-D.03: 2:30-3:30 p.m. Models of State-Level 3D Science Assessment Reform

Invited – Nathan Dadey, Center for Assessment, Dover, NH

Shifting assessment practices to reflect the three dimensions of the Next Generation Science Standards (NGSS) has, and continues to be, a challenging endeavor. In this presentation, the approaches taken by five state departments of education to reform assessment practices are summarized. These approaches provide one starting point for those engaging in assessment reform – at any level, from classroom to state – and this presentation provides access to state materials were possible.

Session PAR-D.04A High School

Monday, July 20, 2:30–3:30 p.m. Sponsor: AAPT

PAR-D.04A: 2:30-3:30 p.m. Analyzing Classroom Discussions on the Underrepresentation of Women in Physics*

Contributed – Benjamin J. Archibeque, Florida International University, Miami, FL 33199

Geoff Potvin, Zahra Hazari, Raina Khatri, Florida International University

Engaging in discussions about the underrepresentation of women have been found to increase women's interest in physical science-related careers and improve their physics identities. Understanding deeply these conversations and how they develop may offer insight into the ways in which teachers can support women in physics classrooms. To this end, we recorded two different sections of an experienced high school physics teacher while implementing a lesson about the underrepresentation of women in physics developed as part of the STEP UP project. In this talk, we will present a comparative analysis of students' argumentation during these two classes.

*This work is supported by the National Science Foundation under Grant No. 1720810, 1720869, 1720917, and 1721021

PAR-D.04A: 2:30-3:30 p.m. We Love Physics: Infusing Your AP Physics C Curriculum with Service Learning

Contributed – Eric A. Walters, Marymount School of New York, Staten Island, NY 10314

As poet George Herbert once noted, "In doing, we learn." Service learning offers students the opportunity to engage in "a wide range of experiences, which often benefits the community, while also advancing the goals of a given curriculum." In this interactive session, participants will discuss the mechanisms and strategies for infusing service learning opportunities into the AP Physics C: Mechanics curriculum to demonstrate their knowledge and understanding of advanced physics concepts in a real-world context. We will also discuss how students planned, designed, and created walkSTEMs, customized, interactive physics-based learning experiences for Central Park to stimulate inquiry and spark curiosity. Participants will review student projects, and brainstorm other meaning service learning projects for physics. You'll also hear from students as they discuss the benefits and challenges of this new learning model.

Enhancing Coursework through Service Learning. (2019, June 1). Retrieved June 2, 2020, from https://apcentral.collegeboard.org/courses/collaborations-with-ap/ap-we-service

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Session PAR-D.04B General Relativity in the High School Classroom

Monday, July 20, 2:30–3:30 p.m.

Sponsor: Committee on Contemporary Physics Co-Sponsor: Committee on Educational Technologies

PAR-D.04B: 2:30-3:30 p.m. General Relativity in the High School Classroom

Invited – Charlie Payne, North Carolina School of Science and Mathematics, Durham, NC 27705-3577

Given current cutting-edge science that is in the news, from Gravitational Waves to Particle Physics to GPS, Relativity has a place in the high school physics classroom. I will discuss the Why, Where, and How of putting General Relativity into the classroom. With activities from sources such as the Perimeter Institute, OzGrav, and LIGO, students can delve into a conceptual model of General Relativity in a variety of ways beyond reading and videos. These will include hands-on as well as VR and AR activities that have worked in my own classroom setting.

PAR-D.04B: 2:30-3:30 p.m. Introducing General Relativity via Hands-on Activities

Invited – Damian Pope, Perimeter Institute, North Waterloo, ON N2L 2Y5 Canada

General relativity is one of the most modern, powerful, and beautiful theories in all of physics. Yet, it's also complex and rarely taught in high school physics. This session will share some cheap, simple, hands-on activities for introducing high school students to general relativity. Building on what students already know about Newtonian gravity, the activities including modelling curved spacetime with stretchy fabric and tape and introducing the equivalence principle by dropping a bottle of water into freefall.

Session PAR-D.04C Neutrino Physics in the Classroom

Monday, July 20, 2:30–3:30 p.m.

Sponsor: Committee on Contemporary Physics Co-Sponsor: Committee on Physics in High Schools

PAR-D.04C: 2:30-3:30 p.m. How To See Neutrinos

Invited – Nathaniel Tagg, Otterbein University, Physics Department, Westerville, OH 43081-2006

Neutrino experiments are impressive: they are huge, they require measure nearly-undetectable particles, and recently have been capturing high-resolution "pictures" of neutrino-matter. We will show some tools for displaying this physics to high-school audiences (as well as professional physicists) and describe some of the challenges in translating real, raw data into understandable ideas.

PAR-D.04C: 2:30-3:30 p.m. Neutrino Experiments Inspire Students

Invited – Marla Glover, Purdue University, Lafayette, IN 47905

Many students in high schools have misconceptions about frontier science experiments. They may think that there is nothing new for them to discover or that they do not have the background necessary to understand what is happening in these experiments. Yet students can use classical physics to analyze neutrino experimental data and draw conclusions. This talk will describe my students' analysis of neutrino data through conservation of momentum. The audience can participate as students for a very brief time to get the feel of being the investigator. I will also share the reaction of my students to using this activity.

Session PAR-D.05 K-12 (Intro UG, AD UG) Physics Courses and Labs in the Shadow of COVID19

Monday, July 20, 2:30–3:30 p.m. Sponsor: AAPT

PAR-D.05: 2:30-3:30 p.m. Applying "Gameful Learning" in a Remote Introductory Physics Course

Contributed – Lauren Rast, The University of Alabama at Birmingham, Birmingham, AL 35233

We have implemented a framework for personalized remote learning in an introductory algebra-based physics course at the University of Alabama at Birmingham. This framework, developed to address issues related to equity and inclusion, is based on a combination of strategies from physics education research and best practices in online learning. Our approach centers around the Gameful Learning pedagogy. Within this framework, we have incorporated several interventions including (1) the adaptive learning platform ALEKS for mathematical remediation (2) activities in metacognition and (3) a physics teaching-assistant managed "virtual help desk". The implementation of this framework, materials developed, and experiences delivering the curriculum to a diverse student population during COVID-19 will be discussed.

PAR-D.05: 2:30-3:30 p.m. Covid-19: An Opportunity to Drive the Undergraduate Introductory Physics Curriculum Toward Change

Contributed – Stephanie L. Bailey, Chapman University, Orange, CA 92866

Given the development of the Covid-19 global pandemic during the Spring semester of 2020, proctoring an in person, comprehensive, written final was no longer an option. While I considered the alternatives, I began to question the learning goals of the course and the value of a traditional final exam. I want my students to continue to think about the course material outside the classroom, to gain a deeper appreciation of the subject, and to reflect on the course as a meaningful and influential life experience. To bring meaning, there must be elements of community, civic responsibility, and personal growth. To that end, students were matched with local seniors, those more vulnerable to loneliness due to the pandemic. They met with their senior via Zoom to discuss connections between course material and the current social, economic, and political context as well as the current coronavirus pandemic and public health in general.

PAR-D.05: 2:30-3:30 p.m. Giving Students Agency Increased Engagement at Just the Right Time

Contributed – Blake Laing, Southern Adventist University, Collegedale, TN 37315

Following the example in "Developing scientific decision making by structuring and supporting student agency" by N.G. Holmes, et al, students designed the research question in a three-week sequence and a written lab report was replaced with an online synchronous oral lab report, followed by time for questions from student colleagues. I will report on enhanced student engagement in class and in office hours and will share anecdotal comments. Students participated in a "belonging intervention". I will share practical lessons learned.

N.G. Holmes, Benjamin Keep, and Carl E. Wieman, Phys. Rev. Phys. Educ. Res. 16, 010109 (2020)

PAR-D.05: 2:30-3:30 p.m. Lessons From Remote Testing

Contributed – Tetyana Antimirova, Ryerson University, Toronto, ON M5B 2K3 Canada

Canadian Universities suspended regular in-person classes around mid-March due to the growing concerns about the pandemics. At my Department, the switch to the emergency remote teaching proceeded relatively smoothly, with remote classes up and running within one week. The synchronous lectures and office hours were conducted via zoom. It helped that the asynchronous online homework already existed as a part of a regular course. Not surprisingly, the real challenge turned out to be a remote testing part. The talk will discuss the challenges of running a traditional exam remotely, and the pressing need for the meaningful alternative ways of evaluating the students while teaching remotely.

PAR-D.05: 2:30-3:30 p.m. Online Introductory Physics Labs During Covid-19

Contributed – Amber Sierra, Arkansas Tech University, Russellville, AR 72801

Jessica PC Young, Arkansas Tech University

Like many institutions during Spring 2020, our university quickly switched to online instruction, and we will share our experiences. We wrestled with how to turn the remaining labs into online labs and tried different methods in our Introductory Physics 1 and Physics 2 Labs. We also deliberated on whether or not to reduce the number of labs required for the semester and how to keep the Teaching Assistants employed. Additionally, we made plans to improve the quality of our online labs in the possibility of a return to virtual instruction in the Fall 2020 semester.

PAR-D.05: 2:30-3:30 p.m. Responses from Introductory Physics Students During the Remote Learning Transition

Contributed – Richard L. Pearson III, Embry-Riddle Aeronautical University, Daytona Beach, FL 32114

Chad M/ Rohrbacher, Embry-Riddle Aeronautical University

Sudden closure of campus facilities due to the COVID-19 pandemic during the academic spring term of 2020 required the delivery of a multi-section, calculus-based introductory physics course to be administered in a remote, online manner. The transition for the courses required an adjustment of all formative and summative assessments, delivery of course lectures, communication avenues, office hour availability, and battles with technology. This poster explores the attitudes, perceptions, conceptual understanding, and overall impressions obtained from student responses to an attitudes survey, a force concept inventory, as well as exam and quiz self-reflection wrappers. Student data is comprised of pre- and post-transition results and comments. An examination of the impact on student learning from both a qualitative and quantitative view reveals relevant practices (both effective and ineffective) for dealing with unforeseen disruptions in a multi-section, introductory physics course.

PAR-D.05: 2:30-3:30 p.m. Letting Students Discover the Laws of Nature Using Interactive Video

Contributed – Matthew Ted Vonk, University of Wisconsin River Falls, River Falls, WI 54022

David T. Brookes, California State University Chico

Eugenia Etkina, Rutgers University

Peter H. Bohacek, Pivot Interactives

Anna Karelina, St. Mary's College of California

Many science instructors aspire to let students discover the laws of nature on their own but find it can be logistically difficult and time consuming to put in practice. In addition, the data that students collect are often more equivocal than one would hope. Further, all of these challenges are confounded by a shift toward online delivery modes. One practical way to let students discover how the universe works is using interactive video. Interactive video uses high resolution recordings of scientifically interesting events that students can characterize for themselves using built-in tools. In many cases, students can also change important parameters in the video (mass, frequency, velocity, pH, etc) which lets them ask their own questions, design their own experiments to answer those questions, and then collect and analyze the results to reach data-driven conclusions.

PAR-D.05: 2:30-3:30 p.m. Transition to Remote Lab Instruction: A National Study

Contributed – Heather J. Lewandowski, University of Colorado Boulder, Boulder, CO 80309

Alexandra Werth, Michael Fox, Jessica Hoehn, University of Colorado Boulder

Benjamin Pollard

Due to the COVID-19 pandemic, colleges and universities across the U.S. transitioned to teaching labs remotely during the beginning of 2020. We conducted a rapid study of the impact of the transition to remote labs using responses to student and instructor surveys and interviews. Our goals for the study include (1) measuring the effect of a rapid transition to remote learning on students' epistemologies and expectations of experimental physics in the context of lab courses and (2) identifying and categorizing the variety of strategies taken by instructors to enable students to access laboratory-like learning remotely. We collected thousands of student responses and over 100 instructor responses to the surveys. We will present the initial results of this study with the aim of providing ideas for teaching remote, online, and hybrid model lab courses in the time of a pandemic.

PAR-D.05: 2:30-3:30 p.m. Transitioning to a Fully Remote One Term Introductory Lab in Two Weeks: Early Results

Contributed – Paul R. DeStefano, Portland State University, Portland, OR 97201-0751

Ralf Widenhorn, Portland State University

At one point in March 2020, many instructors of introductory lab courses had to perform a magic trick, transitioning their courses from in-person, hands-on lessons to distance-learning. Portland State University uses a quarter system, and this transition was achieved in a couple weeks between the end of the Winter and the beginning of the Spring terms. While Winter term was effectively still all in-class, Spring term became a fully remote course. The topics covered in our Spring term are waves, optics, and thermodynamics. We designed a curriculum using simulations resembling the in-class labs and a term long student project. The project highlighted experimental design, modeling, and measurement uncertainty. We asked students to pick their own topic and work with tools they had at home. We present our transformed course curriculum and preliminary research results on the effect of the new curriculum and environment on student attitudes.

PAR-D.05: 2:30-3:30 p.m. Transitioning to Online Instruction with Next Gen PET

Contributed – Lawrence Todd Escalada, University of Northern Iowa, Department of Physics, Iowa Cedar Falls, IA 50613

Alison A. Beharka, University of Northern Iowa

Next Generation Physical Science and Everyday Thinking (Next Gen PET) – a research-based, guided-inquiry, physical science curriculum has been implemented at the University of Northern Iowa (UNI) in a required science course for elementary education majors since fall 2016. We teach the studio version of Next Gen PET in 4 sections of the course each fall and spring Semester. Since summer 2016, we have offered an online version of the course for 6 weeks to help meet demand for the course. In spring 2020, the course transitioned from on-campus, in-person instruction to online instruction in March due to the outbreak of COVID-19. This presentation will share how we have transitioned to on-line instruction with Next Gen PET and include insights we have gained with comparisons made of going online by choice versus being forced due to COVID-19.

Session PAR-D.06 Per Curriculum and Instruction II

Monday, July 20, 2:30–3:30 p.m.

Sponsor: AAPT

PAR-D.06: 2:30-3:30 p.m. Designing for Cultural Relevance in Observational Astrophysics at Texas State

Contributed – Danny Barringer, Texas State, San Marcos, TX 78666

Alice Olmstead, Brianne Gutmann, Audiel Maldonado, Rose Najar, Texas State

Racial and ethnic minority students rarely see themselves and their cultural backgrounds reflected in undergraduate STEM courses. In response, education research scholars have presented a broad vision for inclusive teaching in the form of culturally relevant pedagogy. However, implementing culturally relevant pedagogy in the classroom requires significant, intentional work from curriculum designers and instructors, and there is no single blueprint for designing for cultural relevance. In this talk, I will describe the collaborative development process for a new upper-division Observational Astrophysics course in the Physics Department at Texas State and the work we have done to make the course more culturally relevant to our student body. I will highlight what we have learned from students during the development and first implementation of the course.

PAR-D.06: 2:30-3:30 p.m. Developing Scientific Abilities While Learning Physics Through the ISLE Approach

Contributed – David T. Brookes, California State University, Chico, CA 95929

Eugenia Etkina Rutgers, The State University of New Jersey

Peter Bohacek, Henry Sibley High School

Matthew Vonk, University of Wisconsin, River Falls

Anna Karelina, St. Mary's College of California

Prior research has shown that students can develop scientific reasoning abilities by engaging in authentic scientific investigations in a course following the Inves-

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tigative Science Learning Environment (ISLE) approach. In our current project, we set out to answer two questions: a. Can students develop scientific reasoning abilities through video-based experiments in place of experiments with physical apparatus? b. What are the affordances and constraints of each environment (video experiments versus real experiments)? To answer those, we created and implemented five video-based ISLE learning cycles (v-ISLEs) and used a quasi-experimental design in a class of 96 students. We randomly assigned 2 lab sections to the vISLE condition and another two lab sections to an apparatus condition. Both engaged in the identical experiment sequence. We will present how students developed and displayed scientific reasoning abilities in their lab reports and in exam questions that were created to specifically examine scientific reasoning.

PAR-D.06: 2:30-3:30 p.m. Epistemological Beliefs and Learning: An Example from Resource-Oriented Instructional Materials*

Contributed – Lauren C. Bauman, Quest University, Canada BC V8B 0N8

Amy D. Robertson, Seattle Pacific University

Lisa M. Goodhew, University of Washington

Past research suggests that students' epistemological framing affects their learning of physics content. In this talk, we will investigate this idea in the context of resource-oriented instructional materials. Resource-oriented instructional materials aim to elicit and build from student resources for understanding physics — context-dependent "pieces of knowledge" which can be leveraged to develop sophisticated scientific understandings. We will explore a case in which students' epistemological framing affects their experience of our resources-oriented instructional materials and discuss implications for instructional design.

*This work is supported in part by NSF grant numbers 1914603 and 1914572

PAR-D.06: 2:30-3:30 p.m. Facilitating Ethics Discussions in Physics Classrooms at Texas State University

Contributed – Brianne N. Gutmann, Texas State University, San Marcos, TX 78666

Egla Ochoa-Madrid, Alexander Vasquez, Daniel Barringer, Alice Olmstead, Texas State University

The absence of direct discussions about the intersections of science and society in classrooms reinforces the idea that physics is purely objective and removed from societal impact or influence. This messaging can justify students' disengagement from social responsibility, leave them unprepared to use ethical reasoning in their careers, and isolate students who feel commitment to their communities. At Texas State University, we developed two units to scaffold student discussions around ethics in physics classrooms: a unit about The Manhattan Project (in Modern Physics) and a unit about the Thirty Meter Telescope (in Observational Astrophysics). This talk will discuss the motivation and development of the units, then share some emerging themes from the Manhattan Project implementation. Using video-recordings of classroom interactions, I will highlight group dynamics that limit and enhance students' engagement, consider why these dynamics may have emerged, and discuss their implications for facilitating complex ethical reasoning among students.

PAR-D.06: 2:30-3:30 p.m. Lessons from Teaching Ethics Using the Thirty Meter Telescope Controversy

Contributed – Alexander M. Vasquez, Texas State University

Brianne Gutmann, Daniel Barringer, Alice Olmstead, Texas State University

It is important for physics students to develop ethics knowledge, yet this is rarely taught in physics classes. We are addressing this limitation in our physics classes at Texas State University. Here, we focus on teaching about the ethics of building the Thirty Meter Telescope (TMT) in Hawaii for an observational astrophysics class. We developed resources for students to make informed decisions about this complex issue. The unit encompasses an introduction of the TMT, a local perspective in San Marcos, a history of Hawaii, and perspectives about the TMT relative to formal ethical frameworks. In this talk, we will present data from this new unit in Spring 2020 including students' video-recorded classroom conversations and their written work. We will highlight what worked well in our design and what could be improved in order to support the community of physics educators and education researchers in teaching about ethics in physics classes.

PAR-D.06: 2:30-3:30 p.m. Rediscovery of a child-Centered Japanese Educational Approach: Hypothesis–Experiment Class

Contributed – Michael M. Hull, University of Vienna, Austrian Educational Competence Centre, Division of Physics, Vienna, Austria

Saiki Kitagawa, Haruki Abe, Haruhiko Funahashi, Kyoto University, Graduate School of Human and Environmental Studies

Hiroshi Yokotani, Kyoto International University Academy

Hypothesis–Experiment Class (HEC) is the educational approach proposed by Itakura in 1963. Since that time, a number of HEC curricular materials have been developed to teach students of all ages a wide range of topics in both natural and social sciences. Although Hatano and Inagaki introduced HEC to the West in the 1980s, it was done in service of discussing findings in cognitive science, and HEC itself has received little attention outside of Japan. That is beginning to change, however, with the recent translation and publication of the book "Hypothesis-Experiment Class (Kasetsu)" in 2019. HEC has been compared with the well-known Predict-Observe-Explain (POE) approach as well as other educational approaches, but there are some salient features that make HEC unique. In this presentation, we will discuss how HEC is similar to and different from other educational approaches, looking in particular at a specific HEC lesson on background radiation.

Session PAR-D.07 PER: Student Content Understanding, Problem-Solving and Reasoning II

Monday, July 20, 2:30–3:30 p.m. Sponsor: AAPT

PAR-D.07: 2:30-3:30 p.m. Boys' and Girls' Interest in and Conceptual Understanding of Circuits

Contributed – Jan-Philipp Burde, University of Tübingen, Tübingen, HE 72076 Germany

Thomas Wilhelm, Goethe University

Martin Hopf, University of Vienna

Claudia Haagen-Schützenhöfer, University of Graz

Verena Spatz, TU Darmstadt

Understanding the basic concepts of electricity represents a major challenge to most students in lower secondary schools. In particular, students often fail to develop a robust understanding of voltage. Furthermore, research has shown that girls tend to have a lower interest in physics than boys. However, it is unclear whether decades of research on students' conceptual difficulties e.g. with voltage as well as research into ways to promote girls' interest have had a significant impact on physics classrooms. For this reason, the conceptual understanding of electric circuits as well as the interest in physics of N = 1207 traditionally taught students in Germany and Austria was assessed using a multiple-choice test. The talk will focus on the key findings of this assessment which suggest that girls are still not as interested in physics as boys and that students do not have an adequate conceptual understanding of voltage even after instruction.

PAR-D.07: 2:30-3:30 p.m. Group Exams to Promote Consistency Checking in Student Reasoning*

Contributed – Alistair G. McInerny, North Dakota State University, Fargo, ND 58105 Fargo, ND 58102

Mila Kryjevskaia, North Dakota State University

Many students tend to provide intuitively appealing (but incorrect) responses to some physics questions despite demonstrating (on similar questions) the formal knowledge necessary to reason correctly. While these inconsistencies are typically persistent even in active learning environments, we believe that adding a group component to the exam may engage students sufficiently to resolve these instances of inconsistent reasoning. In our study, students were given opportunities to revisit their answers to questions known to elicit strong intuitively appealing (but incorrect) responses in a collaborative group component of an exam immediately following a traditional individual component. Students discussed their responses with group members but were required to submit their own answers and reasoning. In this presentation, we will examine the effectiveness of a collaborative group exam approach in addressing and resolving inconsistencies in student reasoning and will compare the effectiveness of this approach to a more traditional peer instruction technique.

*This material is based upon work supported by the National Science Foundation under Grants Nos. DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, DUE-1821561, DUE-1431940, DUE-1431541, DUE-1431857, DUE-1432052, and DUE-1432765.

PAR-D.07: 2:30-3:30 p.m. Instructional Pragmatism: Using a Variety of Evidence-based Approaches Flexibly to Improve Student Learning

Contributed – Paul D. Justice, University of Cincinnati, Cincinnati, OH 45202-6844

Emily Marshman, Chandralekha Singh, University of Pittsburgh

Instructional pragmatism is essential for successfully adopting and adapting evidence-based active engagement (EBAE) approaches in that instructors should view improving teaching and learning as a process and not get disheartened if a particular EBAE approach does not produce the desired outcome. Instructional pragmatism entails keeping a variety of EBAE methods in one's instructional toolbox and using them flexibly as needed to improve student learning and continuously refining and tweaking one's implementation of the EBAE approaches to make them effective. Here we illustrate an example of instructional pragmatism in which a quantum mechanics instructor did not give up when an EBAE method involving implementation of a sequence of clicker questions on addition of angular momentum did not yield expected learning outcomes even though it was found effective earlier. Instead, the instructor remained optimistic, viewing improving teaching and learning as a process, and pulled out another EBAE method from his tool box that did not require him to spend more time on this topic in class. In particular, the instructor created an opportunity for students to productively struggle with the same problems they had not performed well on by incentivizing them to correct their mistakes out of class. Student performance on one of the addition of angular momentum problems posed on the final exam suggests that students who corrected their mistakes benefited from the task and learned about addition of angular momentum better than those who did not correct their mistakes. Encouraging and supporting physics instructors to embrace instructional pragmatism can go a long way in helping students learn physics because it is likely to increase their persistence in using various EBAE approaches flexibly as they refine and tweak their implementation for their students. We thank the National Science Foundation for support.

PAR-D.07: 2:30-3:30 p.m. Interactive Video-Enhanced Tutorials: Design to Support Effective Problem-Solving Strategies*

Contributed – Alexandru Maries, University of Cincinnati, Cincinnati, OH 45220

Kathleen Koenig, Joe Ross, University of Cincinnati

Robert Teese, Michelle Chabot, Rochester Institute of Technology

Interactive video-enhanced tutorials (IVETs) involve web-based activities which lead students through a solution using expert-like problem-solving approaches, such as those needed for solving problems using Newton's Second Law. The IVETs, which are based in part on the tutorials created at the University of Pittsburgh, are designed using multimedia principles of learning and research on human learning and memory. The tutorials are adaptive and provide different levels of scaffolding depending on students' needs. They are also affect-adaptive, such that additional guidance is provided to students who indicate they are confused, frustrated, or bored while completing the IVET. This presentation will showcase one of the IVETs and its various design features.

*Work supported by the NSF IUSE Program (DUE #1821396)

PAR-D.07: 2:30-3:30 p.m. Interactive Video-Enhanced Tutorials: Impact on Student Problem-Solving Abilities*

Contributed – Kathleen M. Koenig, University of Cincinnati, Cincinnati, OH 45221

Robert Teese Rochester Institute of Technology

Alexandru Maries University of Cincinnati

Joe Ross University of Cincinnati

Michelle Chabot Rochester Institute of Technology

Interactive video-enhanced tutorials (IVETs) involve web-based activities which lead students through a solution using expert-like problem-solving approaches, such as those needed for solving problems involving conservation of energy or linear momentum. Under NSF funding we have been developing and evaluating multiple IVETs for use with college students in introductory physics. This presentation will showcase our research methods and the impact of various IVETs on student problem-solving abilities.

*Work supported by the NSF IUSE Program (DUE #1821396)

PAR-D.07: 2:30-3:30 p.m. Investigating Causal Inference in Physics to Understand Student Difficulties

Contributed – Eric Kuo, University of Illinois at Urbana-Champaign, Champaign, IL 61801

Benjamin M Rottman, Timothy J. Nokes-Malach, University of Pittsburgh

Valid causal inferences are key to answering many qualitative physics questions. However, while causal reasoning is a well-studied topic in psychology and cognitive science, it is not clear if or how causal reasoning impacts learning and performance in physics education. We hypothesize that uncovering the causal dimensions of physics reasoning can help unify our understanding of student difficulties across different physics topics. We used Bayesian causal networks to design a set of causal questions for simple physical systems that spans the range of possible causal inferences: forward inference using causes to reason about effects, backward inference using effects to reason about causes, and inferring the state of one cause from another cause. We will present data on response patterns for these causal questions and discuss how Bayesian causal networks may be a generative framework for understanding documented student difficulties and informing new instructional approaches in physics education.

PAR-D.07: 2:30-3:30 p.m. Measuring and Predicting the Mathematical Preparedness of Introductory Physics Students*

Contributed – Dakota H. King, Mesa, AZ 85203

David E. Meltzer, Arizona State University

Instructors who teach introductory physics courses may be working with the assumption that their students are fluent with middle-school- and high-school-level mathematics. As reasonable as this assumption may seem, our data, which includes over 5,000 hand-written mathematics diagnostics administered at three large state universities, has consistently shown that students struggle with basic mathematics (graphing, trigonometry, geometry, and algebra) to a significant degree. From our large and campus-diverse samples, we have found remarkable consistency between populations and have noticed interesting trends. For example, we have found specific items that seem to predict overall diagnostic performance with impressive accuracy, independent of campus and course. Here, we focus on an in-depth analysis of these predictive items while elaborating on our interpretation of the results. We will also briefly discuss our plans and ideas to address this deep-rooted issue.

*Supported in part by NSF DUE #1504986 and #1914712

PAR-D.07: 2:30-3:30 p.m. Radiating Is a Verb

Contributed – Andy P. Johnson, Black Hills State University, Spearfish, SD 57799

A radiation literate person understands what radiation is, where it comes from, and how it can do harm. This is a rare case in America. Students enter physics courses - and typically earn a college degree - with undifferentiated views of radioactive sources, radiation, contamination, and radiation harm. Also students also do not initially distinguish between ionizing and electromagnetic radiation. It all is one vague, bad thing – radiation. Many students talk about radiation as something like a substance or an infectious agent. Beyond a widespread lack of education, part of the problem is the noun form "radiation" which suggests the ontological category of "substance". Coming to understand particles radiating is a key step in understanding radiation in general. This talk will characterize the undifferentiated view, and propose that "radiating" is an idea to be aimed for in radiation literacy.

PAR-D.07: 2:30-3:30 p.m. Response Patterns by Introductory Physics Students on Mathematics Diagnostic Tests*

Contributed – David E. Meltzer, Arizona State University College of Integrative Sciences and Arts, Mesa, AZ 85212

Dakota H. King, Arizona State University

Over 5000 diagnostic tests consisting of about 20 high-school-level mathematics problems were administered in part or in full to introductory physics students at four campuses of three large state universities; topics covered were trigonometry, algebra, geometry, and graphing. Despite substantial performance differences among the four population samples, response patterns were consistent; they showed error rates ranging from 20-80% on problems involving mathematical skills normally taken for granted by college physics instructors. Performance on algebra problems consistently declined when symbols were substituted for numerical coefficients. Both written and interview data indicated that many errors were due to difficulty in combining basic operations in more complex problems, or perhaps by simple "carelessness" in doing so. Despite the wide variety of diagnostic topics, results on a very small subset of items predicted overall scores with high accuracy. We will report initial results of testing an on-line instructional tool aimed at improving student performance.

*Supported in part by NSF DUE #1504986 and #1914712

PAR-D.07: 2:30-3:30 p.m. Using Diagrams as a Reflection Tool in Introductory Physics

Contributed – Catherine M. Herne, SUNY New Paltz, New Paltz, NY 12561-1135

Wyatt Mehmeti, SUNY New Paltz

We routinely employ diagrams along with self-reflection in introductory physics, as research has shown that performance on tests and overall conceptual understanding improve when students draw diagrams when reflecting on material taught in class. Our earlier study examined performance on tests and found that using diagrams plus self-reflection led to moderate improvement on test scores. In the current study, we examined three areas: scores on tests, improvements in diagram skill, and frequency of drawing unsolicited diagrams. We found that students benefited more from diagram-based reflections, rather than word-based. This session presents the results of this study and implications for student success.

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PAR-D.07: 2:30-3:30 p.m. Visual Attention While Interpreting Motion Graphs

Contributed – Jennifer L. Docktor, University of Wisconsin - La Crosse, La Crosse, WI 54601

Jose Mestre, University of Illinois at Urbana-Champaign

Motion graphs are an important part of learning kinematics, yet many beginning students struggle with graph interpretation. In this study, introductory physics students and graduate students viewed 42 different graphs of position, velocity or acceleration versus time on a computer screen while their eye movements were recorded using a stationary eye tracker. Participants were asked to match a region of the graph with a text description of an object's motion. We will summarize key findings about visual attention for selected questions and link these eye-gaze patterns to both question performance and audio-recorded explanations of reasoning.

PAR-D.07: 2:30-3:30 p.m. What do Students Know About Electromagnetic Wave Generation?

Contributed – Nickolas Gray, North Carolina State University, Raleigh, NC 27607

Robert Beichner, North Carolina State University

As part of a research project, we are interviewing students in a second semester introductory physics course as well as graduate physics students about the generation of electromagnetic waves. We have, so far, interviewed 43 intro level students and 20 graduate students. We found that only 10 of 43 intro students could identify accelerating charges as a source for electromagnetic radiation. 15 of these students came from a course that used the Matter and Interactions text and 7 were able to identify accelerating charges as a source of EM waves. Fully half of the grad students could not answer correctly. If you restrict to graduate students that do not work with radiation as part of their research, 7 of 8 graduate students could not answer correctly. We are continuing to search for specific types of difficulties as well as reasons why students do not seem to grasp this core concept.

Session PAR-D.08 Pre High School

Monday, July 20, 2:30–3:30 p.m.   Sponsor: AAPT

PAR-D.08: 2:30-3:30 p.m. A Model for Argumentation in Integrated STEM for Physical Science*

Contributed – Carina M. Rebello, Purdue University, West Lafayette, IN 47907-2040

Yuri B. Piedrahita Uruena, Jeffrey W. Murray, Purdue University

The Next Generation Science Standards (NGSS Lead States, 2013) performance expectation includes a tight integration of eight science and engineering practices and requires students to make deeper connections between science and engineering. One of the eight science and engineering practices emphasizes engaging in argumentation from evidence in both science and engineering contexts. An integrated STEM approach leverages teaching STEM content alongside STEM practices. The development of meaningful learning experiences that foster deeper consilience among STEM disciplines and utilize argumentation to solve design problems is a major goal of integrated STEM education. However, there are disciplinary distinctions in argumentation. We need to consider how various disciplines or communities of practice understand and implement argumentation. To that end, we propose a model for argumentation in integrated STEM. We will discuss implications of designing curricula in middle school context that integrates the learning of physics with other STEM disciplines while infusing argumentation.

*Supported in part by NSF Grant 1712201.

PAR-D.08: 2:30-3:30 p.m. Changes in Teacher Self-Efficacy In Knowing and Teaching Energy*

Contributed – Michael C. Wittmann, University of Maine, Orono, ME 04469-5709

Paul Wilson, Levi Lucy, University of Maine

Teacher self-efficacy is as important as teacher content knowledge: do the teachers see themselves as able to know and teach the material well? In the Maine Physical Sciences Partnership, we worked with teachers to improve the teaching and learning of middle and high school physical science. As part of this work, we had teachers take and analyze a survey on energy that their students would be answering. One group was recorded as they discussed the survey, question by question. Telling their story involves describing the survey and providing examples of their low and high self-efficacy statements. They answered every question correctly, constructing their responses slowly but carefully. But, they began the activity by expressing profound uncertainty in their content knowledge. By the time the activity ended, the level of confidence they expressed in their knowledge and their ability to teach it had increased considerably.

*Supported in part by NSF grants 0962805 and 1222580.

PAR-D.08: 2:30-3:30 p.m. Classroom Experiences & Self-Efficacy in AP Physics 1

Contributed – Marta R. Stoeckel, Tartan High School / University of Minnesota, Oakdale, MN 55128

Self-efficacy is an important predictor of intention to continue in physics and is influenced by students' experiences in the classroom. In this study, students in AP Physics 1 were interviewed at the end of the course to identify the kinds of classroom experiences that impacted their beliefs about their ability to do physics. Labs were mentioned by nearly all students as an important factor, though whether students saw labs as having a positive or negative impact on their self-efficacy depended on certain characteristics of the lab. Many students, especially boys, also discussed peer interaction while working problems as an experience that improved their self-efficacy. Many students also discussed assessment feedback as evidence their teacher believed they are good at physics, though boys focused on assessments where they scored well while girls discussed assessments where they scored poorly.

PAR-D.08: 2:30-3:30 p.m. Eleven Years of Faculty Professional Development in STEM: Lessons Learned

Contributed – Debbie A. French, Winston Salem, NC 27109

Sean Hauze, San Diego State University

R. Mark French, Purdue University

Tom Singer, Sinclair Community College

Doug Hunt, Southern Wells High School

The STEM Guitar Project has provided professional development institutes for K-16 faculty for the past 11 years. Over 450 teachers have been trained, which has resulted in over 20,000 students impacted by the project. The STEM Guitar Project instructs participants on how to build an electric guitar, acoustic guitar, or design and cut out a custom guitar body with a CNC, as well as provides training for how to teach integrated STEM concepts using the guitar. A summary of the lessons learned from over a decade of faculty workshops will be presented. Evaluation methods, research results, and next steps will be discussed.

PAR-D.08: 2:30-3:30 p.m. GFO Copywrite: Research-based Materials for Recruiting STEM Teachers

Contributed – Savannah L. Logan, Colorado School of Mines, Lakewood, CO 80228-4802

Jared B. Breakall, Wendy K. Adams, Colorado School of Mines

There is a serious shortage of secondary science and math teachers across the United States. Part of this shortage can be attributed to a lack of research-based recruitment materials. To this end, we have developed written and visual materials for recruiting future STEM teachers as part of the Get the Facts Out (GFO) project. We have tested and refined our materials through faculty and student focus groups at several demographically and geographically diverse US universities over the last two years. Most recently, we have collected large-scale data on effective recruitment materials via a national online survey. Our findings provide insights into optimal recruitment strategies, and we will share our unique findings based on location, demographics, and target audience. We will also discuss our testing and refinement strategies through interactive activities. This project is supported by NSF DUE-1821710.

PAR-D.08: 2:30-3:30 p.m. Smashing Pumpkins

Contributed – Tonya S. Coffey, Appalachian State University, Boone, NC 28607-4308

Joshua Gregory, Raimie Neibaur, Appalachian State University

Jon Orr John, McGregor Secondary School

Blowing up watermelons and pumpkins with rubber bands is a popular K-12 demonstration of the conversion of spring potential energy into kinetic energy. Although there are informal investigations into this demo, no systematic studies in peer-reviewed journals exist. We examine a large data set (>800 busted pumpkins) collected by Jon Orr, a Canadian math teacher who authored a Desmos activity on learning scatter plots using this fun demo. We also conduct our own independent experiments, to verify some surprising relationships in this exciting demo. We share our findings and lesson plans that can be used either in the classroom or in K-12 outreach events.

PAR-D.08: 2:30-3:30 p.m. Tracking Student Mindset Shifts in the HS Physics Classroom

Contributed – Debbie S. Andres, Paramus High School, Paramus, NJ 07652

Adoption of the Next Generation Science Standards (NGSS) encourages teachers to incorporate various new types of instruction into their classrooms. This leaves us questioning the effectiveness of these new methods on students' physics content knowledge, as well as students' beliefs in their own ability to learn. Students will step into a physics classroom with a predetermined mindset regarding their ability to learn physics. How can we measure the development of their mindset in the context of learning physics? In my freshman physics classes I integrate elements of Standards-Based Grading and the Investigative Science Learning Environment approach. I use a variety of attitudes and beliefs surveys throughout the year to track shifts in students' mindsets. In this talk I share how my students' mindsets have changed and identify elements of my teaching practices that have contributed to these changes.

Session PAR-D.09 Finding and Adapting IPLS Materials from the Living Physics Portal

Monday, July 20, 2:30–3:30 p.m. Sponsor: Committee on Physics in Undergraduate Education

PAR-D.09: 2:30-3:30 p.m. Adapting IPLS Materials for Large Enrollment, Algebra-based, Studio Courses

Invited – Brokk Toggerson, University of Massachusetts Amherst, Amherst, MA 01003-0001

Introductory physics for life science (IPLS) courses can vary wildly in sizes, pre-requisites, major distributions, and pedagogical frameworks. These variations mean some level of adaptation of found materials is almost always required. This talk will focus on the process of adapting materials from the IPLS Portal (and elsewhere) to a two-semester, algebra-based, studio-style IPLS sequence of large enrollment at University of Massachusetts Amherst. In this context, large enrollment means a single instructor, with some TA support, is responsible for two sections of 100 students each in the first semester, and for two sections of 250 students in the second. Therefore, scalability, while maintaining an active learning environment, is a key consideration. Other adaptations motivated by our large number of kinesiology majors, as well as differences arising from algebra- versus calculus-based courses will also be considered.

PAR-D.09: 2:30-3:30 p.m. Adapting Materials for a Transferable IPLS Studio Course

Invited – Xian Wu, University of Connecticut, Mansfield, CT 06269-3046

The University of Connecticut has initiated the transition of its calculus-based intro-physics courses from traditional lecture into interactive studio. Numerous materials have been newly developed or adapted to leverage studio classroom facility to benefit student learning. A mock-up IPLS studio course is taught in the 2020 summer semester with limited enrollment. We would like to share with the PER community the lessons we have learned through the transition so far.

PAR-D.09: 2:30-3:30 p.m. Creating a Biomechanics Course for Future Occupational Therapists – Twice!

Invited – J. Caleb Speirs, University of New England, Biddeford, ME 04005

One week is not enough time to design an entire course, especially a course with unfamiliar subject matter. Yet many educators find themselves in similar or more daunting situations. This talk will describe two iterations of an introductory biomechanics course designed for undergraduates in the field of occupational therapy (OT). More importantly, it will also highlight the ways that the physics education research community aided the course design, both in pedagogical stance and in terms of specific activities and materials. The course itself leads students with no physics background and little math skills through basic mechanics and allows them to productively use and analyze biomechanical models of various "activities of daily living" (ADL's). Largely project based, the course draws from materials posted on the Living Physics Portal in addition to exposing students to published research in OT and asking them to blend their OT perspectives into the course content.

PAR-D.09: 2:30-3:30 p.m. Interactive Simulations of Equilibrium Problems on Human Body

Contributed – Dan Liu, University of Hartford, West Hartford, CT 06117

The curricula of interdisciplinary introductory physics courses for life science programs such as Physics of Sports, Physics of Human Body etc. have a big component of Kinetics in general. Equilibrium is one of the most important chapters with a variety of applications of fundamental physics knowledges including force analysis, Newton's laws and the conditions of equilibrium for translation and rotation. In order to better engage students to learn statics, we start to develop interactive simulations of equilibrium problems on human body and implement the simulation activities in the course Physics of Human Body, which is mainly for students majoring in Physics Therapy, Health Sciences and Rehabilitation Sciences. A couple of the simulations will be shared in the presentation and later in Living Physics Portal.

Session PAR-D.10 Tools for Teaching Computation in Physics

Monday, July 20, 2:30–3:30 p.m. **Sponsor: Committee on Educational Technologies**

PAR-D.10: 2:30-3:30 p.m. Accessible Computation: Teaching Computation In Physics Through Browser-Based Platforms

Poster – Merideth A. Frey, Sarah Lawrence College, Bronxville, NY 10708

Computational skills are a necessity in the modern workforce. However, determining how to teach these skills in a way that can be easily accessible for all students is a daunting challenge. As a one-person physics department in a small, liberal arts institution, I have aimed to build up the physics curriculum with an emphasis on transferrable experimental and computational skills, all while being accessible to as many students as possible. This work includes computation-based introductory physics laboratories, computational assignments in a non-major course on chaos, and computational essays in an intermediate lab-based class on resonance. Each course primarily uses a different browser-based platform (spreadsheets, Glowscript, Google Colaboratory) that was chosen for its accessibility and ease-of-use. I will discuss the various successes and challenges I have encountered teaching with these different computational tools, and I look forward to receiving feedback and ideas for future iterations of this ongoing project.

PAR-D.10: 2:30-3:30 p.m. Cloud-based Tools and Software for Integrating Computation into a Physics Curriculum

Invited – Jason E. Ybarra, Bridgewater College, Department of Physics, Bridgewater, VA 22812

I will present an overview of some of the cloud-based tools and software to facilitate integration of computation into a physics curriculum. These tools allow students to do computational work without having to install and configure software on their personal computers. The ability to share their code in real-time with classmates allows for collaborative learning, and sharing with the instructor provides an avenue for fast feedback. Examples of assignments using cloud-based tools will be presented.

PAR-D.10: 2:30-3:30 p.m. Computational Toolkits in Quantum Mechanics

Poster – Jay Wang, UMass Dartmouth, Dartmouth, MA 02747-2300

Trevor Robertson, UMass Dartmouth

Computation has much to offer in terms of teaching quantum mechanics. In this presentation we give specific examples of use of computation in quantum mechanical problems. We also discuss standard toolkits either well-known, used in research or found in software libraries, and not-so-standard tools one can implement themselves. Examples utilizing numerical and visualization techniques for solving time-dependent and time-independent quantum systems will be discussed (see also http://www.faculty.umassd.edu/j.wang/) including superposition, scattering flux, eigenstates in periodic structures, evolution of uncertainties, and quantum dots.

PAR-D.10: 2:30-3:30 p.m. Impact of Learning Assistants on Problem Solving in Computational Thinking

Invited – Bahar Modir, Texas A&M University-Commerce, Commerce, TX 75429-3011

Macon Magno, Robynne Lock, William G. Newton Texas A&M University-Commerce

In fall 2019, we started to implement the learning assistant program into our middle division physics courses at Texas A&M University-Commerce. As part of this effort, we have implemented the learning assistant program for the first time to our computational physics course. The class time is a combination of lecture and group problem solving. We will analyze the interactions between the learning assistant-student, student-student and student-instructor. To investigate, we have recorded the student group work during coding to find the effect of a learning-assisted classroom on students computational thinking and the role of learning assistants in nudging students towards more productive approaches.

PAR-D.10: 2:30-3:30 p.m. Navigating Computational Thinking Practices for High School Physics Curricula

Poster – Theodore Bott, Michigan State University, Warren, MI 48092-2857

Daniel P. Weller, Paul W. Irving, Marcos D. Caballero, Michigan State University

Within the last 15 years, computational thinking (CT) has emerged as a focal point of K-12 education. Numerous frameworks have outlined the practices involved when students and teachers engage in CT. These frameworks discuss how CT practices should be understood, implemented, and assessed in the classroom. While curricular expectations around this topic are becoming clearer, teachers (especially high school STEM instructors) still express a significant need for assessment strategies in the classroom. In light of this, we have begun to develop an assessment that will measure high school and early college instructors' perspectives on

CT practices. Currently, we are constructing an open-ended pilot survey that will help us understand which practices are relevant to teachers and how familiar teachers are with these practices. Once we have identified the CT practices that teachers are interested in evaluating, we will move to the next step of the assessment development: creating an open-ended free-response questionnaire to administer to students.

PAR-D.10: 2:30-3:30 p.m. Simulated Annealing with the POV-RAY Ray Tracing Program: Photo-Realistic Crystal Growth

Poster – John R. Walkup, California State University, Fresno, Fresno, CA 93740

The Persistence of Vision Raytracer (POV-Ray) is a free software tool for creating photo-realistic, three-dimensional graphics. Using a simple -- albeit capable -- programming syntax, POV-ray offers a fun way for students to develop basic programming skills such as the use of random number generation, variable declarations, conditional statements, and loop structures. In this presentation, the presenter will describe how the animation capability of POV-ray can model Monte Carlo techniques such as Markov chains and the Metropolis algorithm to simulate the annealing process fundamental to crystal growth.

PAR-D.10: 2:30-3:30 p.m. The Friendly Command Line: Computational Physics on the Unix Shell

Invited – Walter W. Freeman, Syracuse University 215 Physics Building Syracuse, NY 13244

Often the skills required to use the Unix/Linux command line are perceived as old-fashioned, difficult to learn, and unnecessary. However, the Linux command line is an extraordinarily flexible environment for programming, data reduction and analysis, simulation, and visualization, and is thus in wide use throughout the physics research community and beyond. These skills are surprisingly accessible to students. In this talk, I will argue that the command-line environment is a pedagogically beneficial environment for students to learn computational physics, with advantages both within the classroom and beyond it, and demonstrate some of the tools and methods the computational physics students at Syracuse use for simulation, visualization, animation, and data analysis.

PAR-D.10: 2:30-3:30 p.m. The Opportunities and Challenges of Minimally Working Programs

Invited – W. Brian Lane, Jacksonville University, Jacksonville, FL 32211

When assigning a computational activity, it's a common best practice for physics educators to provide students with a minimally working program (MWP) that the students modify, rather than asking them to code from scratch. On-line coding platforms such as GlowScript and Trinket make it easy to deploy MWPs and for students to share their completed work. I'll discuss how we can supplement this best practice with pre-class video tutorials about our MWPs and outline a process for scaffolding student learning using MWPs. I'll also describe some challenges one can encounter with MWPs (such as, "Do students really learn how the MWP works?" "Do skills and understanding really carry over from one activity to the next?") and open the floor for discussion about how we might address those challenges.

PAR-D.10: 2:30-3:30 p.m. Video Analysis of Variation in Computational Thinking Practices in Physics

Poster – Daniel P. Weller, Michigan State University, East Lansing, MI 48823

Marcos D. Caballero, Paul W. Irving, Michigan State University

Computational thinking has been emphasized as a main science and engineering practice in the Next Generation Science Standards. However, learning objectives outlined by the standards are written in vague terms that complicate the implementation and assessment of this topic in the classroom. This is especially problematic for high school teachers who have limited experience with computation and are looking to integrate computational modeling in their physics or physical science classrooms. In this study, we explore the variation in computational thinking practices that physics students demonstrate when working through in-class coding activities. Video data of multiple student groups were collected in one high school teacher's physics and physical science classrooms. The data was analyzed to create a codebook that describes the different ways students engage in computational thinking practices. Ultimately, this work will help practitioners better understand how to identify these practices in a high school physics setting.

Session PAR-D.11 SPS Awards and Trivia Contest (LIVE)

Monday, July 20, 2:30–3:30 p.m. Sponsor: AAPY

Session PAR-E.01 Computational Thinking in Physics II

Tuesday, July 21, 10:00–11:00 a.m. **Sponsor: Committee on Educational Technologies** **Presider:** *Chris Orban*

PAR-E.01: 10:00-11:00 a.m. How to use C++ Program to Implement the Root Finding Algorithms of Polynomial Equations

Contributed – Rolex Rao, Future Start & Candle Light-A non-profit, Sunnyvale, CA 94087

Austin Liu, Future Start & Candle Light-A non-profit

How to use C++ program to implement the root-finding algorithms of polynomial equations Rolex Rao and Austin Liu Future Start, 1570 Tenaka Place, Apt 1, Sunnyvale, CA94087 1. In finding the roots of a polynomial with real coefficients, most of the challenge comes from the complex conjugate pairs. In the beginning, the C++ programs iteration was based on the recursive equation, the data didn't converge like a chaos. Based on the analysis on the function discovered by Mr. Rao, we developed an algorithm to figure out the angle of the complex root before finding its magnitude. 2. After finding the angle of the complex root, we obtained two equations for the magnitude of the root. But the complex conjugate pair came on the road again. Amazingly out of our brain storm, Mr. Rao proposed a constant elimination method, which went around the problem caused by conjugate pair and runs well in Austin's C++ program. 3. The most difficult challenge is the combination of all multiple roots, alternating roots, complex conjugate pair, and even conjugate pairs with identical magnitudes. Again, Austin's C++ program successfully verified Mr. Rao's algorithm, we now call it land-drifting or land-sliding algorithm. 4. This project is one of the best examples learning through computing and that computing supports the scientific discovering and science theory gives the direction for innovative computing methods development.

PAR-E.01: 10:00-11:00 a.m. Hungry Hungry Hamsters: Intro Physics Students Program a Game

Contributed – Evan Halstead, Skidmore College, Saratoga Springs, NY 12866-1632

Students in undergraduate introductory physics courses do not always appreciate the importance of computational skills when it comes to physics. To help motivate students in this area, I have developed a simple game that introduces students to a few essential computational constructs: loops, if-statements, and Euler-Cromer integration. The game involves physics that cannot be done on paper. Students played the game on the first day of class, and then were tasked with reproducing the game. As a class, the students generated a checklist of essential features. Each then used the checklist to program a reproduction of the game. Students worked at their own pace, with only minimal instruction on computation in the beginning of the semester. I discuss successes and lessons learned.

TUESDAY

PAR-E.01: 10:00-11:00 a.m. Integrating Computation into an Intermediate Mechanics Course

Contributed – Andrew Richter, Valparaiso University, Valparaiso, IN 46383

In an effort to begin the task of suffusing computational approaches throughout or physics and astronomy curriculum, we recently decided to adapt a required, sophomore-level, intermediate mechanics course to include an introduction to scientific programming and numerical methods. Given that this course is typically used to develop the mathematical tools students require in their third and fourth years, such as solving differential equations, working with advanced vector manipulations, and processing matrices, it seems that adding programming approaches fits perfectly with the course goals. Of course, there are drawbacks as well, since adding material requires removing other material that has long been part of the course. In this talk, I will present my experience, both the positive and negative aspects, and I will argue that the overall result has been beneficial. I will also discuss my very recent conversion of the course from using Java to using Python with Jupyter notebooks.

PAR-E.01: 10:00-11:00 a.m. Navigating Computational Thinking Practices for High School Physics Curricula

Contributed – Theodore E. Bott, Michigan State University, Warren, MI 48092-2857

Daniel P. Weller, Paul W. Irving, Marcos D. Caballero, Michigan State University

Within the last 15 years, computational thinking (CT) has emerged as a focal point of K-12 education. Numerous frameworks have outlined the practices involved when students and teachers engage in CT. These frameworks discuss how CT practices should be understood, implemented, and assessed in the classroom. While curricular expectations around this topic are becoming clearer, teachers (especially high school STEM instructors) still express a significant need for assessment strategies in the classroom. In light of this, we have begun to develop an assessment that will measure high school and early college instructors' perspectives on CT practices. Currently, we are constructing an open-ended pilot survey that will help us understand which practices are relevant to teachers and how familiar teachers are with these practices. Once we have identified the CT practices that teachers are interested in evaluating, we will move to the next step of the assessment development: creating an open-ended free-response questionnaire to administer to students.

PAR-E.01: 10:00-11:00 a.m. The Theory of a Complete Root Finding Algorithm of Polynomial

Contributed – Rolex Rao, Future Start & Candle Light-A non-profit, Sunnyvale, CA 94087

The theory of a new complete root-finding algorithm of polynomial functions Rolex Rao, Future Start, 1570 Tenaka Place, Apt 1, Sunnyvale, CA94087 We provide a theory for several complete and thorough root-finding algorithms of polynomial functions. Our algorithms are interestingly different. The most powerful algorithm can efficiently handle the all-out attack of multiple roots, alternating roots, complex conjugate pairs and even conjugate pairs with identical magnitude. The other one, however, can find the angle of the complex root prior to finding its magnitude, and so forth. Since other functions can be converted into polynomial functions through Taylor's expansion, our root-finding approach will be useful in the teaching and research of math, physics and technology. By the way, this is a successful example of teaching through computing. My student, Austin Liu, who made C++ programs to verify the theoretical concepts, is a high school student.

PAR-E.01: 10:00-11:00 a.m. Utilization of Computational Quantum Chemistry in Addressing Misconceptions and Threshold Concepts in Traditional Quantum Chemistry Curriculum

Contributed – Wilson Gichuhi, Tennessee Tech University, Cookeville, TN 38505

Dusty W. Henson, Tennessee Tech University

In many universities, all quantum-mechanics based courses are intended to introduce to the student fundamental topics and theory that includes wave particle duality and obtaining exact analytical solutions to the Schrödinger equation for simple systems such as the hydrogen atom. The transition from a solvable quantitative Schrödinger equation-based model in the hydrogen atom to a more sophisticated qualitative model involving non-hydrogenic atoms and molecules introduces many misconceptions to students. Such misconceptions can become a major barrier to students' capability of understanding and solving further analytical problems in quantum chemistry, throwing both the instructor and the student in a 'threshold concept arena'. We show how computational chemistry can be integrated into a typical undergraduate quantum chemistry lecture curriculum to assist in learning nontrivial topics such as Franck Condon principle and Born Oppenheimer approximation.

PAR-E.01: 10:00-11:00 a.m. Video Analysis of Variation in Computational Thinking Practices in Physics

Contributed – Daniel P. Weller, Michigan State University, East Lansing, MI 48823

Marcos D. Caballero, Paul W. Irving, Michigan State University

Computational thinking has been emphasized as a main science and engineering practice in the Next Generation Science Standards. However, learning objectives outlined by the standards are written in vague terms that complicate the implementation and assessment of this topic in the classroom. This is especially problematic for high school teachers who have limited experience with computation and are looking to integrate computational modeling in their physics or physical science classrooms. In this study, we explore the variation in computational thinking practices that physics students demonstrate when working through in-class coding activities. Video data of multiple student groups were collected in one high school teacher's physics and physical science classrooms. The data was analyzed to create a codebook that describes the different ways students engage in computational thinking practices. Ultimately, this work will help practitioners better understand how to identify these practices in a high school physics setting.

Session PAR-E.02 Effective Practices in Educational Technology II

Tuesday, July 21, 10:00–11:00 a.m. **Sponsor: AAPT** **Presider:** *Andy Garvin*

PAR-E.02: 10:00-11:00 a.m. An OER Inventory of Innovative Online Physics Problems

Contributed – Yun Zhang, University of Missouri, Columbia, MO 65211

I have created a new inventory of innovative online introductory physics problems based on the findings of state-of-the-art research in physics pedagogy and my deep awareness of students' needs. This inventory currently contains more than 250 items selected from the OpenStax College Physics Textbook and my own collection of 15 years of exams in the College Physics 1 course. These problems are implemented on the Varafy Online platform, and are readily integrated into Canvas (or other Learning Management Systems). They can be easily tailored to each individual instructor's teaching style. This inventory is licensed under the Creative Commons Attribution 4.0 International License and is available at no cost to instructors.

PAR-E.02: 10:00-11:00 a.m. Doing Flight Physics with Smartphones and Real-time Data Analysis

Contributed – Lutz Frank Kasper, University of Education, Schwaebisch Gmuend, Germany

Patrik Vogt ILF, (Institute for Teacher Education) Mainz (Germany)

Flight tracking apps like flightradar24 offer multiple possibilities for doing flight physics in high school and undergraduate physics courses. Those apps provide users with real-time data about a huge amount of airplanes around the world. Apart from regular information (aircraft type, airline, starting point and destination) we can get highly relevant data from a physics point of view, such as ground speed, true airspeed, and vertical speed as well, furthermore GPS-altitude, and temperature. Depending on the app a part of the data is free obtainable. Access to the full data set often requires a subscription. In our talk we will give an overview about modeling and doing "data science". From the app we can determine glide ratio, acceleration, amount of thrust, lift coefficient, flow resistance, and the elevation-dependent temperature. Moreover, collaborative use of those technologies and apps enables teachers to design nationwide or even international projects.

PAR-E.02: 10:00-11:00 a.m. Ensuring Student Preparation Using Pressbooks and the Edfinity Homework System

Contributed – Brokk K. Toggerson, University of Massachusetts Amherst, Amherst, MA 01003-0001

Emily E. Hansen, University of Massachusetts Amherst

In a flipped classroom model, students are expected to master a base level of information before coming to class. Such a structure can result in not only more class time to explore more complex topics, but also a more equitable classroom. To achieve these goals, the level of knowledge students are expected to master must be appropriate. Moreover, quality materials and support, which focus solely on what is needed for preparation, must be available so that all students, regardless of prior experience, can come prepared for class. In order to ensure accessibility, these materials should be free or very low cost and conform to Universal Design for Learning principles. In this talk we present a free-and-open multi-modal textbook developed in Pressbooks for a second semester IPLS course at University of Massachusetts Amherst. Student mastery of the preparation is further developed through formative online assignments in the low-cost Edfinity homework system.

PAR-E.02: 10:00-11:00 a.m. Insights From Computation in Quantum Mechanics

Contributed – Jay J. Wang, UMass Dartmouth, Dartmouth, MA 02747-2300

Trevor Robertson, UMass Dartmouth

Of all subjects, quantum mechanics is arguably the one that can benefit the most from integration of computation into the curriculum. Unlike classical mechanics or electromagnetism, quantum mechanics has only few time-independent problems, countable with one hand, that are analytically solvable. There are virtually no time-dependent problems with analytic solutions. This poses a clear challenge to helping students in introductory quantum mechanics in understanding the concepts and developing intuition or insights. Even for the straightforward analysis of two states in a superposition, the bedrock of quantum mechanics, it is hardly possible to follow the time evolution without the use of computation. In this presentation we discuss the integration of computation in an otherwise traditional undergraduate quantum mechanics course to deal with the challenge. Activities (see http://www.faculty.umassd.edu/j.wang/) include simple visualization of superposition, quantum revival, determination of eigenstates, wave packet motion, and screened hydrogen atoms.

PAR-E.02: 10:00-11:00 a.m. Leading Effective Professional Development Remotely Using Zoom

Contributed – Shane E. Wood, QuarkNet, Shoreview, MN 55126

Deborah Roudebush, QuarkNet

QuarkNet is an NSF-funded professional development (PD) program that provides science teachers the means to develop their skills to bring authentic research and data analysis into the classroom. We will discuss some of our challenges and opportunities in leading PD during this time of remote learning, the technologies we are using, and some best practices in leading PD remotely.

PAR-E.02: 10:00-11:00 a.m. Letting Students Discover the Laws of Nature Using "Interactive" Video

Contributed – Matt Vonk, University of Wisconsin River Falls

David T. Brookes, California State University Chico

Eugenia Etkina, Rutgers University

Peter Bohacek, Pivot Interactives

Anna Karelina, St. Mary's College of California

Many science instructors aspire to let students discover the laws of nature on their own but find it can be logistically difficult and time consuming to put into practice. In addition, the results are often more equivocal than one would hope. One practical way to let students discover how the universe works is using interactive video. Interactive video uses high resolution recordings of scientifically interesting events that students can characterize for themselves using built-in tools. In many cases, students can also change important parameters in the video (like mass, frequency, velocity, pH, etc). This lets them ask their own questions, design their own experiments to answer those questions, and then collect and analyze the results to reach data-driven conclusions.

PAR-E.02: 10:00-11:00 a.m. Simulation Suite for Intermediate Undergraduate Course on Vibrations and Waves

Contributed – Timothy A. Stiles, Kettering University, Flint, MI 48504

Computer simulations for intermediate and advanced undergraduate courses provide students with tools that aid in visualizing difficult concepts. A suite of ten simulations has been developed for use in a sophomore/junior level course on vibrations and waves. This includes topics such as driven, damped oscillations; nonlinear oscillations of a pendulum; coupled oscillators; sound waves; and interference and diffraction. A feature of these simulations is the display of quantitative information about the phenomena in the simulation. For example, users can set the frequency and pressure amplitude of a plane sound wave, but the simulation also displays the particle velocity and displacement amplitudes and an animated graph of pressure, displacement and particle velocity of the wave. These simulations have been part of homework and discussion assignments in the related course.
https://sites.google.com/kettering.edu/tstiles/home/teaching-demonstrations

PAR-E.02: 10:00-11:00 a.m. Student Learning Outcomes with Hybrid Computer Simulations and Hands-On Labs*

Contributed – Sheila Sagear, Departments of Astronomy and Physics, Boston University, Boston, MA 02215

Emily Allen, Science Department, The Governor's Academy

Manher Jariwala, Andrew Duffy, Department of Physics, Boston University

Computer simulations for physics labs may be combined with hands-on lab equipment to boost student understanding and make labs more accessible. Hybrid labs of HTML5-based computer simulations and hands-on lab equipment for topics in mechanics were investigated in a large, algebra-based, studio physics course for life science students at a private, research-intensive institution. Computer simulations were combined with hands-on equipment and compared to traditional hands-on labs alone using an A/B testing protocol. Learning outcomes were measured for the specific topic of momentum conservation by comparing student scores on post-lab exercises, related quiz and exam questions, and a subset of questions on the Energy and Momentum Conceptual Survey (EMCS) administered before and after instruction for both groups. We will present our findings of this study in the context of previous work and discuss the larger implications of the use of simulations in physics education.

*Funded by NSF grant DUE 1712159.

TUESDAY

Session PAR-E.03 Introductory Courses

Tuesday, July 21, 10:00–11:00 a.m. Sponsor: AAPT

PAR-E.03: 10:00-11:00 a.m. An Instructional Approach to Facilitate Introductory Physics Students' Transfer of Learning

Contributed – Bijaya Aryal, University of Minnesota Rochester, Rochester, MN 55904

Kyle McLelland, University of Minnesota Rochester

We have designed a teaching/learning sequence, for an introductory level physics course, that includes 'activity session' and 'application session'. The layout of the teaching/ learning space, the design of lessons, and the use of teaching/ learning strategies aim to improve student learning of physics for students majoring in health sciences. The aim of the activity session, where students learn by doing in the classroom, is to help students build knowledge with the help of instructors and peers. The application session aims to assess student retention of knowledge from the prior session, facilitate the consolidation of knowledge, and provide students with a platform to integrate ideas in transferring skills to non-routine problem-solving tasks. To assess the impact of this educational effort, we evaluate student learning of knowledge and problem-solving skills. We administer physics education research-based tests as both pre- and post-test to assess student learning of concepts. To evaluate students' problem-solving performance we use a validated rubric.

PAR-E.03: 10:00-11:00 a.m. Disc Golf Physics

Contributed – Joseph A. Johnson, Mercyhurst University, Erie, PA 16546-0001

Nathan Wise, Mercyhurst University

Disc golf is one of the fastest growing sports in the world. Played much like traditional golf, players attempt to throw a plastic disc to a target basket in the fewest number of throws possible. Like traditional golf, disc golf involves many interesting concepts from physics and kinesiology. Yet little is known within the disc golf community about the physical phenomena that governs the sport. In an attempt to explore and explain the physics behind the disc golf shot, an independent research project was conducted by an undergraduate student and a physics professor. This research describes the differences in flight patterns between the major types of disc golf discs and a video analysis describing throwing mechanics and the resulting effects on flight characteristics. This presentation will involve the description of the student research project and a description of how these concepts can be integrated into introductory physics courses.

PAR-E.03: 10:00-11:00 a.m. Dynamic Analysis of the Falling Process of Disc Tower

Contributed – Shidong Zhu, JiuLongHu campus, Southeast University, Nanjing, Jiangning

Identical discs are stacked one on top of another to form a freestanding tower, if the bottom one gets pulled out, the upper ones will stagger a distance from each other. From the slow motion it can be found that the disks will not stagger before falling on the ground. The reason for the stagger is the tower's rotation around the center of mass. And we work out the condition that the tower does not collapse in the first order approximation. Our experimental results coincide the graphs very well.

PAR-E.03: 10:00-11:00 a.m. Online Practice of Trigonometry and Linear Equations Skills for Physics

Contributed – Beatriz E. Burrola Gabilondo, The Ohio State University, Columbus, OH 43212

Andrew Heckler, The Ohio State University

Our overall goal is to develop "diagnose-and-practice" resources to help students in our introductory physics courses improve their accuracy and fluency on math skills necessary for success. In this phase of the project we focused on developing and testing online practice exercises. In each of 11 lecture sections, all students were assigned to practice either trigonometry or linear equations using our online platform multiple times throughout the semester. We observed that on average, students in both conditions decreased in pre -to-post time on all items, with the relevant treatment group showing larger decrease for some of the relevant test items. Accuracy scores were high with no differences between conditions. We also tracked student accuracy and time during their practice throughout the semester and found student improvement in accuracy and/or time for some categories, but not for others. A new practice protocol will be implemented in AU2020 based on these results.

PAR-E.03:10:00-11:00 a.m. Sensemaking Instruction in Introductory Physics

Contributed – MacKenzie Lenz, University of Utah, Corvallis, OR 97330

Kelby T. Hahn, Paul J. Emigh, Elizabeth Gire, Oregon State University

Thinking like a physicist is often hailed as a goal of introductory physics. Sensemaking strategies provide an avenue for developing physicist-like reasoning. Strategies such as drawing a picture, identifying assumptions, checking units, and analyzing limiting cases can help develop students' physicist-like reasoning. Explicit sensemaking instruction aids in expanding students' views about sensemaking and helps them develop habits that persist beyond explicit prompting. In this talk we present ways of scaffolding and fading sensemaking strategies as well as rewarding their use in introductory physics courses.

PAR-E.03: 10:00-11:00 a.m. Teach Intuitive and Practical Quantum Mechanics with Real Schrödinger Rquations

Contributed – Julian Chengjun Chen, Columbia University, White Plains, NY 10603-1718

Quantum mechanics is the centerpiece of modern physics. Teaching quantum mechanics have been difficult because of complex numbers, Hilbert space, and interpretations. We show that a real formulation of quantum mechanics without complex numbers and Hilbert space is included in Schrödinger's 1926 papers. The legitimacy and advantages of such a real formulation were justified in 1960s. High-caliber quantum mechanics textbooks in real formulation existed since 1970s in France. Experimental observations of atomic and molecular wavefunctions using scanning tunneling microscopy necessitates a real formulation. Practically, in chemical physics and condensed-matter physics, real wavefunctions are sufficient, especially regarding to density-functional theory (DFT). Outlined here is a freshman-sophomore course of real quantum mechanics covering a wide range of applications to dispense with complex numbers and Hilbert space. As shown, the derivation of the real Schrödinger equations is transparent, the mathematics is elementary, and the interpretation is intuitive.

PAR-E.03: 10:00-11:00 a.m. Trajectory of Flying Card

Contributed – Yanbo Wang, China, Jilin, Changchun Changchun, Nanguan 130000 China

Shidong Zhu, Donghao Wu

A card with an initial velocity and initial angular velocity can fly in the air for a while, and finally it will fall on the ground. During the flying process, the air friction and viscous resistance act on the card continuously so that the kinestate of the card changes all the time. This makes the trajectory of a flying card look like a question mark. We first use kinetic equation to analyze the trajectory and make an assumption. Then, we use camera to collect necessary statistics of a flying card to explore the real trajectory and check the assumption we have put forward before. Our experimental and theoretical results match well.

PAR-E.03: 10:00-11:00 a.m. Untold Secrets of the Slowly Charging Capacitor

Contributed – Drew Milsom, University of Arizona, Tucson, AZ 85721

The slowly charging capacitor is the standard example used to illustrate that the displacement current is needed in Ampere's Law if we want to correctly determine the magnetic field between the capacitor plates. However, it is not widely recognized that in any quasi-static situation the magnetic field can also be determined using the Biot-Savart Law with just real currents. In this presentation, we will see how including the effects of the surface currents on the plates helps explain the resulting magnetic field both between the plates and outside the plates. It is very likely that the results will surprise most viewers. Discussing these issues in an upper division physics course would provide students with additional physical insight into this interesting system.

PAR-E.03: 10:00-11:00 a.m. Using Interactive Simulations in Adaptive Calculus-based General Physics Courses

Contributed – Priya Jamkhedkar, Portland State University

Ralf Widenhorn, Theodore Stenmark, Misty Hamideh, Toai Nugyen, Portland State University

This talk summarizes the use of interactive simulations and activities integrated with an adaptive online platform to teach introductory calculus-based physics at Portland State University. We discuss the designing of activities using Geogebra and Phet simulations to teach and illustrate physics concepts. Simple activities highlighting concepts in topics such as the movement of a disturbance, interference, beats, standing waves, harmonics in waves and sound, refraction and image formation in geometrical optics, diffraction, and interference of light, thermodynamics, vectors, forces, and friction in mechanics. The design of the simulations is such that they seamlessly integrate into a course that aims to promote active and engaged learning.

PAR-E.03: 10:00-11:00 a.m. Voltage Diagrams: A New Graphical Representation for the Loop Law

Contributed – Paul J. Emigh, Oregon State University, Corvallis, OR 97333

The loop and junction laws typically form the foundations of the study of electric circuits in introductory physics. However, these rules can often be difficult for students to reason about conceptually, especially in circuits with multiple loops. We have developed a graphical representation of the loop law that can be used to bolster students' conceptual understanding of voltage drops and gains in an electric circuit. We discuss the representation itself, possible variants of the representation, and thoughts from using the representation in a large introductory physics course.

Session PAR-E.04 PER: Assessment, Grading and Feedback II

Tuesday, July 21, 10:00–11:00 a.m. Sponsor: AAPT

PAR-E.04: 10:00-11:00 a.m. Applying Machine Learning to Automatically Assess Middle-School Students' Argumentation

Contributed – Xiaoming Zhai, University of Georgia, East Lansing, MI 48824

Kevin Haudek, Michigan State University

Chris Wilson, BSCS Learning Sciences

Tina Cheuk, Jonathan Osborne

Recent science education reform calls for argumentation as one of the central practices in science classrooms. However, evaluating student argumentation proficiency is challenging. Based on an existing learning progression of argumentation and grade-appropriate objectives, we developed a measure for middle-school students in three contexts (e.g. kinetic theory of gases) of 19 constructed response items. Experts coded responses from 932 middle-school students for components of argumentation and used these coded responses to train machine learning algorithms for each item. The algorithms were validated using a cross-validation approach. We found that the machine-human agreements are robust, with a mean Cohen's kappa=0.75, SD=0.08. We further applied a many-facet Rasch analysis and found the item difficulty in this measure is well aligned with the established learning progression. The algorithms developed in this study can be used in classrooms to automatically evaluate students' argumentation proficiency.

PAR-E.04: 10:00-11:00 a.m. Assessing Mathematical Reasoning: The Physics Inventory of Quantitative Reasoning

Contributed – Suzanne White Brahmia, University of Washington, Department of Physics, Seattle, WA 98195-1560

Alexis Olsho, University of Washington

Andrew Boudreaux, Western Washington University

Trevor Smith, Rowan University

Mathematical reasoning flexibility across physics contexts is a desirable learning outcome of introductory physics, where the "math world" and "physical world" meet. Physics Quantitative Literacy (PQL) is a set of interconnected skills and habits of mind that support quantitative reasoning about the physical world. We present the Physics Inventory of Quantitative Literacy (PIQL), which is a validated instrument that assesses students' proportional reasoning, co-variational reasoning, and reasoning with signed quantities as they are used in physics. Unlike concept inventories, which assess conceptual mastery of specific physics ideas, the PIQL is a reasoning inventory that can provide snapshots of student ideas that are continuously developing. We are exploring analysis methods of student responses on the PIQL that will allow for assessment of hierarchical reasoning patterns, and thereby potentially map the emergence of mathematical reasoning flexibility throughout the introductory sequence, and beyond. (NSF DUE-1832836, DUE-1832880, and DUE-1833050)

PAR-E.04: 10:00-11:00 a.m. Evaluating Gender Fairness in the FCI via the LASSO Platform

Contributed – John B. Buncher, North Dakota State University, Department of Physics, Fargo, ND 58102

Drew Aubrey, Purdue University

Recently, there has been a lot of interest in assessing the gender bias in a number of widely-used conceptual surveys. One recent study by Traxler et al. found several items on the FCI to be biased towards male students. In this work, we examine if the same items are problematic when administered in an online format across different institutions (via the LASSO platform). Using Classical Test Theory (CTT) and Item Response Theory (IRT), we find that most FCI items are substantially unfair to women, supporting the findings of Traxler et al. Additionally, items that had the most bias towards men are consistent with those Traxler et al. suggested removing to reduce the overall gender bias in the FCI.

PAR-E.04: 10:00-11:00 a.m. Evaluating Impact of GTA Training in a Mixed-Reality Classroom Simulator

Contributed – Tong Wan, University of Central Florida, Orlando, FL 32816

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

In this study, we evaluate the impact of rehearsing teaching skills in a classroom simulator on GTAs' instructional practices in combined tutorial and laboratory sections of an algebra-based introductory physics sequence over three semesters. GTAs participated in different numbers of simulator rehearsal sessions across the three semesters: no simulator training, one session, and four sessions. We conducted 109 classroom observations for 23 GTAs, using a modified version of Laboratory Observation Protocol for Undergraduate STEM (LOPUS). To classify and characterize GTAs' instructional practices, we conducted a hierarchical cluster analysis and found three instructional styles: "the group-work facilitators", "the whole-class facilitators", and "the waiters." These instructional styles vary in multiple GTA codes, including amount of wait time and posing questions in small groups and whole class. We discuss the characteristics of the instructional styles and distributions of GTAs' use of the styles in each semester.

PAR-E.04: 10:00-11:00 a.m. Gauging Student Attendance and Participation: Generic Clickers Versus TopHat

Contributed – Adebanjo Oriade, Newark, DE 19716

In my practice I have found TopHat [1] a much better tool (than generic clickers) for gauging student attendance and participation. I have used clickers for over six semesters, and TopHat I have used this spring 2020 semester. In this light, the observations I share might be premature, time will tell. TopHat seems better, for reasons like having a wider spectrum of question types, and having an easy to use facility for students to review the questions later. Engagement is vital for active learning since we want students motivated, and we want to have measures of progress towards the learning goals of the course [2]. Our score for attendance was binary while that of participation was measured on a skewed ternary scale. Zoom chat transcripts and Google document chats were also used as gauges. I look forward to learning from you how you gauge engagement and learning in your learning spaces.

[1] https://tophat.com Accessed June 2020. [2] Handelsman, Jo et al. p. 52 Scientific Teaching. W. H. Freeman, 2007.

PAR-E.04: 10:00-11:00 a.m. Modeling Students as Thermodynamic Systems Using the Canonical Ensemble*

Contributed – Trevor I. Smith, Rowan University, Glassboro, NJ 08028-1701

Nasrine Bendjilali, Rowan University

We have previously established a ranking of incorrect responses to FMCE questions using Item Response Theory. In Bock's Nominal Response Model (NRM), each student has an associated latent trait (i.e., understanding of mechanics), and each response is represented by two parameters. One of the parameters is reported as showing the strength of correlation between that response choice and the latent trait. Bock does not interpret the meanings of these parameters; however, the mathematical form of the NRM is identical to the probability of a system being in a discrete degenerate energy state in the canonical ensemble. Through analogy we may interpret the latent trait as relating to the system temperature, and explain why one parameter ("energy") is related to the latent trait but the other parameter ("degeneracy") is not. We may also gain additional information by extending this analogy to consider macroscopic quantities such as average energy and entropy.

*Supported by NSF grant DUE-1836470.

PAR-E.04: 10:00-11:00 a.m. More Representative and Less Biased Methods for Interpreting Student Outcome Data

Contributed – Ben Van Dusen, Iowa State University, Chico, CA 95928

Jayson Nissen, J.M. Nissen Consulting

We address two major issues in the methods PER has historically used to interpret student outcomes on research based assessments (e.g., the FCI). First, PER has historically used normalized learning gain (g) as a normalizing factor to interpret student outcome scores. This is problematic because g has no statistical basis and is biased in favor of high pre-score groups. Second, instructors have been comparing their student outcomes to those in the published literature. This is problematic because the published literature overrepresents outcomes from courses in highly-selective institutions. In this talk we will offer two alternative methods for interpreting student outcomes based on our analysis of a large-scale dataset with representation across the spectrum of institution types. Specifically, we recommend interpreting student outcomes using either a scatter-plot of a large-scale course pretest and posttest scores or an effect size measure (e.g., Cohen's d of Hedges g).

PAR-E.04: 10:00-11:00 a.m. Optimizing Machine Learning to Identify At-Risk Physics Students

Contributed – John C. Stewart, West Virginia University, Morgantown, WV 26506

Recently, machine learning algorithms, primarily random forests, have been used to identify students at risk of failing introductory physics. While these algorithms produced excellent accuracy when identifying students who would receive an "A" or "B" in a physics class, the performance was much worse when identifying students who would receive a "D" or "F". This work investigates multiple pathways to optimize the algorithms to improve performance including using alternate algorithms such as support vector machines, optimization algorithms such as gradient boosting and regularization, and ensemble algorithms which allow multiple different algorithms to vote on the results. This work seeks to identify the limit of accurate prediction with only institutional variables.

PAR-E.04: 10:00-11:00 a.m. Report and Rerun: Closing the Loops in Education

Contributed – Mohamed Abdelhafez, MIT, Cambridge, MA 02139

David E. Pritchard, MIT

We're developing a web-based utility to give instructors next morning formative reports on last night's assignments, including the time and difficulty on questions and videos/readings to guide today's instruction. Together with additional metadata, this information can guide revising the course for rerunning next year. Data are presented using color codes for quickly assessing how well students are doing on individual resources and on the entire assignment. This quickly identifies resources to eliminate or move elsewhere. We use "edx2bigquery" to convert edX log data into Google BigQuery which generates the dynamic reports. It also provides an easy way of adding static metadata via a popup in a modified version of open edX or directly into the resource database. These uses illustrate the desirability of "closing the loop" in education, a powerful way to improve instruction and content. The audience can suggest what information they desire - or to mohamedr@mit.edu

PAR-E.04: 10:00-11:00 a.m. Studying Distractors with ReMNIRT: Reduced Multidimensional Normalized Item Response Theory

Contributed – Byron C. Drury, Massachusetts Institute of Technology, Cambridge, MA 02138

Yunfei Ma, Mohamed Abdelhafez, Dave Pritchard, MIT

John Stewart, West Virginia University

Distractors (i.e. incorrect responses) on research-designed multiple choice instruments are often designed to reflect specific prevalent belief structures among students. Traditional Item Response Theory (IRT) models only consider the correctness of students' responses, not the specific incorrect responses given, and therefore cannot reveal the specific misconceptions held by a population of students. We introduce a new model, ReMNIRT, which extends upon prior work in polytomous IRT by introducing a weight matrix which concisely quantifies what each possible response tells us about the latent skills of students. We apply this model to a data set of pre- and post-instruction administrations of the Force Concept Inventory (FCI) to approximately 17500 students at seven undergraduate institutions. The insight that this analysis gives on the specific ways in which students misunderstand mechanics will help instructors to use the FCI and other research-designed assessments more effectively as formative assessments to inform their teaching.

Session PAR-E.05 PER: Diversity, Equity & Inclusion III

Tuesday, July 21, 10:00–11:00 a.m. Sponsor: AAPT

PAR-E.05: 10:00-11:00 a.m. Creating Interdisciplinary Pathways into Quantum Careers: Opportunities for Physics Departments

Contributed – Michael J. Verostek, University of Rochester, Rome, NY 13440-2540

Benjamin M. Zwickl, Rochester Institute of Technology

Aligning with the National Quantum Initiative and NSF's "Quantum Leap," we are working toward an interdisciplinary approach to quantum information science and technology (QIST) education. We present results from a single institution based on interviews with faculty and administrators in engineering, computing, and the sciences at Rochester Institute of Technology, which suggest that it is feasible and desirable to provide STEM majors with accessible degree pathways that embed quantum-related electives. Combined with results from studies on the skills of quantum industry employees, our results indicate a minor or concentration in QIST provides STEM majors with sufficient preparation for quantum careers, and a new major in QIST is unnecessary. Physics departments could play an essential role in such programs by offering an introductory QIST course open to all STEM majors that prepares students for advanced QIST coursework. We also provide insight into structural barriers that might hinder implementation of this arrangement.

PAR-E.05: 10:00-11:00 a.m. Cultural Exchange Events

Contributed – Ruth Saunders, Humboldt State University, Arcata, CA 95521 United States

This talk describes some events designed to share culture among students and faculty. In order to enhance the participation of women and minoritized students and to elevate the experiences of all students, we must find ways to allow students to bring their whole selves into their studies. The illusion that Physics has no culture is damaging especially those who do not feel welcome. By discussing culture and sharing our culture we can strengthen connections between students and faculty.

PAR-E.05: 10:00-11:00 a.m. How Does the Learning Environment Predict Student Outcomes in Algebra-based Introductory Physics Courses?

Contributed – Sonja Cwik, University of Pittsburgh, Pittsburgh, PA 15217

Kyle Whitcomb, Chandralekha Singh, University of Pittsburgh

Student outcomes in introductory physics courses influence their retention in STEM disciplines and future career aspirations. This study investigates how the learning environment predicts male and female students' outcomes, including grade, self-efficacy, interest, and identity. These findings can be useful to provide support and to create an equitable and inclusive learning environment to help all students excel in algebra-based physics courses.

PAR-E.05: 10:00-11:00 a.m. Impact of Peer Interaction on Male and Female Students' Sense of Belonging in Introductory Physics

Contributed – Alysa D. Malespina, University of Pittsburgh, Pittsburgh, PA 15260

Chandralekha Singh, University of Pittsburgh

We investigate how students' perceptions of interactions with their peers in introductory physics courses predict their sense of belonging in those courses using a validated survey. We also compare male and female students' perceptions of peer interactions when they worked in mixed gender vs. same gender groups. Findings can be useful in creating learning environments in which all students have a high sense of belonging and can thrive while learning physics. We thank the National Science Foundation for support.

PAR-E.05: 10:00-11:00 a.m. In a Physics Curriculum Only Introductory Physics Course Grades Show Gender Differences

Contributed – Kyle Whitcomb, University of Pittsburgh, Pittsburgh, PA 15260

Chandralekha Singh, University of Pittsburgh

Analysis of institutional data for physics majors showing predictive relationships between required mathematics and physics courses in various years is important for contemplating how the courses build on each other and whether there is need to make changes to the curriculum for the majors to strengthen these relationships. We use 15 years of institutional data at a large research university to investigate how introductory physics and mathematics courses predict male and female physics majors' performance on required advanced physics and mathematics courses. We used Structure Equation Modeling (SEM) to investigate these predictive relationships and find that among introductory and advanced physics and mathematics courses, there are gender differences in performance in favor of male students only in the introductory physics courses after controlling for high school GPA. We found that a measurement invariance fully holds in a multi-group SEM by gender, so it was possible to carry out analysis with gender mediated by introductory physics and high school GPA. Moreover, we find that these introductory physics courses that have gender differences do not predict performance in advanced physics courses. Also, introductory mathematics courses predict performance in advanced mathematics courses which in turn predict performance in advanced physics courses. Furthermore, apart from the introductory physics courses that do not predict performance in future physics courses, there is a strong predictive relationship between the sophomore, junior and senior level physics courses.

PAR-E.05: 10:00-11:00 a.m. PER Doctoral Programs and Women Bachelor's Degree Recipients in Physics

Contributed – Susan C. White, American Institute of Physics, College Park, MD 20740

Gary D. White, The George Washington Univ.

It has been shown previously* that PhD physics departments that maintain a doctoral degree specialization in Physics Education Research (PER) for 10 years produce significantly more physics bachelor's degree recipients than PhD departments which do not support such a specialty, even after accounting for department size via their respective numbers of FTE faculty members. Here we report on related work, wherein we investigate the correlation between sustained PER PhD programs in physics departments and the number and proportion of undergraduate physics degrees granted to women as reported by those departments. We use data from past issues of the GradsSchoolShopper publication, and from the surveys of physics departments conducted by Statistical Research Center of the American Institute of Physics.

*And the Survey Says… "PER PhDs & bachelor's degrees" Susan C. White *Phys. Teach.* **55**, 79 (2017); https://doi.org/10.1119/1.4974116

PAR-E.05: 10:00-11:00 a.m. Perceiving Whiteness and Masculinity in Physics Teaching and Learning*

Contributed – Sarah B. McKagan, Alder Science Education Association, Seattle, WA 98122

Wilford T. Hairston, Equitable Development LLC

Amy D. Robertson, Seattle Pacific Universtiy

Rachel E. Scherr, University of Washington Bothell

In the Centering Project, we are studying how whiteness and masculinity show up in the physics classroom, through video of classroom interactions among students and between students and instructors, and in the content and practices of physics, including curriculum. In this talk we present results of this analysis that we think will be relevant for physics educators.

This work is supported in part by NSF DUE 1760761.

PAR-E.05: 10:00-11:00 a.m. Science Cafes as a Collaborative, Informal Event for Professional Learining

Contributed – Mossy Kelly, Galway-Mayo Institute of Technology, Department of Computation and Applied Physics, Galway City, Galway*

Sophie Eden, University of Hull

Bianca Moone, Advance HE

The focus of the talk will be on two events that were run mid-way through a 12-week laboratory course. These events, named 'Science Cafés', were used as an informal way to get students and staff to gather together to collaboratively work on professional development. The theme of the first event was to reflect on the things students do and recognise aspects of professional learning within that experience. The second event was focussed on writing resumés for potential job applications in the future. In the collaborative spirit, this talk will be co-delivered with a student who attended these events who had this to say: "The science cafés were chances to discuss with people who've hired, and been hired by other academics, to talk through what we've done, and have the things which we as students see as routine and part of being a student, actually being very valid scientific experience."

*Sponsored by Ruth Saunders

PAR-E.05: 10:00-11:00 a.m. When the Gatekeeper Says No: Mechanics Students' Resilience and Success

Contributed – Devyn Shafer, University of Illinois at Urbana-Champaign, Urbana, IL 61801

Tim Stelzer, University of Illinois at Urbana-Champaign

What happens to aspiring engineers who do not pass their introductory mechanics class? At UIUC, approximately 11 percent of introductory mechanics engineering students earn a D, F, or W. Just 31 percent of these students go on to earn an engineering degree, compared with the 87 percent of students who pass the course on their first attempt. While most students who perform poorly in their introductory physics class choose a non-engineering major or leave the university altogether, there is a unique subset of initially struggling students who choose to persist in an engineering major. We interviewed engineering seniors in this group to learn about their experiences as engineering students who overcame an initial setback. In this talk, we will discuss big-picture outcomes for students who retake this fundamental course as well as insights into the difficulties some students face and what resources may help them succeed.

PAR-E.05: 10:00-11:00 a.m. Physics-Specific Discourses and White Identity: Examples from Classroom Video*

Contributed – Wilford T. Hairston, Equitable Development LLC N/A, Seattle, WA 98118-0968

Sarah B. McKagan, AlderSEA

Amy D. Robertson, Seattle Pacific University

Rachel E. Scherr, University of Washington

Sociocultural theory has articulated the central role that identity plays in learning, and has pointed to some of the ways in which instructional practices actively interact with discipline-specific identities. The lack of diversity and inclusion within physics suggests that physics instructional practices are actively centering particular identities while marginalizing others. In this talk, we use classroom video to illustrate ways in which physics-specific discourses mediate a particular type of physics identity, one centered around whiteness as a historical and material reality.

*This work is supported in part by NSF DUE 1760761.

Session PAR-E.06 Physics Education Research in Labs II Tuesday, July 21, 10:00–11:00 a.m.

Sponsor: Committee on Research in Physics Education Co-Sponsor: Committee on Laboratories

PAR-E.06: 10:00-11:00 a.m. A Framework of Goals for Writing in Physics Lab Classes

Contributed – Jessica R. Hoehn, University of Colorado, Boulder, CO 80309

H. J. Lewandowski, University of Colorado Boulder

Writing is an integral part of the process of science. In the undergraduate physics curriculum, the most common place that students engage with scientific writing is in lab classes, typically through lab notebooks, reports, and proposals. There has not been much research on why and how we include writing in physics lab classes, and instructors may incorporate writing for a variety of reasons. Through a broader study of multiweek projects in advanced lab classes, we have developed a framework for thinking about and understanding the role of writing in lab classes. This framework defines and describes the breadth of goals for incorporating writing in lab classes, and is a tool we can use to begin to understand why, and subsequently how, we teach scientific writing in physics.

PAR-E.06: 10:00-11:00 a.m. Connecting the Dots: Student Social Networks in Introductory Physics Labs

Contributed – Cole J. Walsh, Cornell University, Ithaca, NY 14850-5645

Daniyar Kushaliev, N.G. Holmes, Cornell University

Students' positions within the social network of a physics classroom has been shown to correlate with students' sense of belonging and performance. Students that are more well-connected in the classroom also tend to persist in physics. Current research in PER aims to understand how different types of active learning classrooms promote the development of students' social networks. In this work, we examine how these networks develop in introductory physics labs. Physics labs offer ample space and freedom for students to interact with their peers and build a network. We use video of students working in labs to capture the interactions between students, examine how network topologies compare between labs designed with different goals, and evaluate how these topologies evolve over the course of a semester. I also discuss the viability and efficiency of using video to construct student networks with large amounts of data.

PAR-E.06: 10:00-11:00 a.m. Model Rocket Engines

Contributed – Erick Agrimson, St. Catherine University, St. Paul, MN 55105

Hannah Rogers, St. Catherine University

Model Rocket engines have provided students at St. Catherine University the opportunity to review concepts about impulse, energy and kinematics. In what is now fondly called 'the rocket lab' students build a rocket at the end of one lab session and then proceed to launch and calculate the altitude the model reaches theoretically using impulse and conservation of energy. Students are then able to experimentally measure the altitude using trigonometry and from an altitude box attached to the nose cone. The lab allows for discussion related to sizing i.e. ½ A vs A in terms of the impulse delivered by the engine. We are also able to talk about how the changing mass generates the thrust needed to propel the rocket skywards. Our students have found this lab to be an effective way to learn these topics in their courses.

PAR-E.06: 10:00-11:00 a.m. Problematizing in Inquiry-based Labs: How Students Respond to Onexpected Results

Contributed – Meagan Sundstrom, Cornell University

Anna Phillips, Natasha Holmes, Cornell University

In traditional labs, instructors provide explicit directions for students to complete experiments and achieve predetermined results that coincide with concepts learned in lecture. However, in inquiry-based labs where students generate their own research questions and procedures, the results of an experiment are often unknown or unexpected. Students in this setting typically find outcomes that do not align with their intuitive predictions or models presented to them in lecture. This perplexing moment in the lab may lead them to take various actions, from collecting more data or asking an instructor, to trying to sweep it under the rug. We call this recognition of a gap in understanding and the subsequent activities that tend to the issue problematizing. I will discuss a study in which we analyzed video of students performing a free fall experiment to determine how they problematize after finding an object's acceleration to be quite different from g = 9.81 m/s^2.

PAR-E.06: 10:00-11:00 a.m. Student Ownership of Lab Projects: Evolution Across Temporal Project Phases*

Contributed – Acacia D. Arielle, Western Washington University, Bellingham, WA 98226

Ira Ché Lassen, Western Washington University; Laura Ríos,California Polytechnic State University San Luis Obispo,; Heather J. Lewandowski, University of Colorado Boulder; Dimitri R. Dounas-Frazer, Western Washington University

[This abstract represents one part of a two-part study; some language is reproduced in another abstract.] Our team is studying student ownership of projects, a significant learning outcome in many project-based lab courses. An empirical model of ownership will support educators and researchers in the practice, design, and implementation of courses that encourage student ownership. Our preliminary model was based on analysis of a subset of survey and interview data from five Western and Midwestern physics departments. In this talk, I will demonstrate how this ownership model maps onto our full dataset, including stimulated recall interviews, and what educational implications emerge from further analysis. In our model, ownership is more than an outcome that develops over time and is achieved by the project's end. Students may or may not experience ownership in any of three phases: choice of topic, execution of methods, and synthesis of results into reports or presentations. *This material is based on work supported by the NSF under Grant Nos. DUE-1726045 and PHY-1734006.

PAR-E.06: 10:00-11:00 a.m. Student Ownership of Lab Projects: Manifestation in Student-Project Interactions*

Contributed – Ira Ché Lassen, Western Washington University, Bellingham, WA 98225-8622

Acacia D. Arielle, Dimtiri R. Dounas-Frazer, Western Washington University

Laura Ríos, California Polytechnic State University San Luis Obispo

Heather J. Lewandowski, University of Colorado Boulder

[This abstract represents one part of a two-part study; some language is reproduced in another abstract.] Our team is studying student ownership of projects, a significant learning outcome in many project-based lab courses. An empirical model of ownership will support educators and researchers in the practice, design, and implementation of courses that encourage student ownership. Our preliminary model was based on analysis of a subset of survey and interview data from five Western and Midwestern physics departments. In this talk, I will demonstrate how this ownership model maps onto our full dataset, including stimulated recall interviews, and what educational implications emerge from further analysis. In prior work, we described ownership as a relationship between students and their projects. Material, cognitive, and affective student-project interactions composed the resulting ownership model. These interactions included student contributions to their projects, student understanding of project topics, and student emotional responses to progress and setbacks.

*This material is based on work supported by the NSF under Grant Nos. DUE-1726045 and PHY-1734006.

PAR-E.06: 10:00-11:00 a.m. What Makes a Good Lab Partner?

Contributed – Danny Doucette, University of Pittsburgh, Pittsburgh, PA 15260 =

Russell Clark,Chandralekha Singh, University of Pittsburgh

Students who take lab courses engage in active, collaborative learning that has the potential to teach scientific thinking skills while also stimulating students' interest in science. In order to understand the impact of collaboration on student learning and experiences in introductory labs, we surveyed more than 450 college physics students about their beliefs and experiences regarding working with a lab partner. While students want a "fair split" of the work, they learn most when they participate equally in all aspects of the lab. Thus, lab courses should be designed to ensure that students participate equally, rather than just splitting up the work.

PAR-E.06: 10:00-11:00 a.m. Implementation of Design Experiments in Large-Scale Introductory Physics Classes

Contributed – Alexander J. Shvonsk,i Massachusetts Institute of Technology

Pushpaleela Prabakar, Jacob White, Peter Dourmashkin, 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 >700 students, with 8 sections total (~90 per section), and is built upon an "active learning" structure, where students interact with each other and online materials during class. We introduced 5 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. 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, how we integrated online components, some considerations with respect to implementation on a large scale, and also report student feedback and E-CLASS results.

Session PAR-E.07 Transforming Physics Curricula to Include Computation Tuesday, July 21, 10:00–11:00 a.m.

Sponsor: Committee on Physics in Undergraduate Education Co-Sponsor: Committee on Research in Physics Education Presider: *Deva O'Neil*

PAR-E.07: 10:00-11:00 a.m. A Portfolio of Data Analytics Classes at Ohio State University

Poster – Donald M. Terndrup, Department of Astronomy, The Ohio State University, Columbus, OH 43210

Em Sowles, Emily Griffith, The Ohio State University

Karen M. Leighly, The University of Oklahoma

We present the design and initial implementation of two data-driven Astronomy courses at Ohio State. Both courses teach fundamental astrophysical and statistical concepts using the Python coding language. Astronomy 1221 is a general-education course for first-year students, about half of whom are majors in Astronomy and Astrophysics. Astronomy 3350 is a majors course for 3rd-year students. We review the main features of these courses and how they prepare students for sophomore- and senior-level astrophysics classes and for starting research in data-intensive projects. Especially in the first-year course, the design is intended to improve retention of female students, who leave the major more often than do male students despite having higher grades in their physics and math courses. Finally, we discuss how Astronomy 1221 will fit into a new general-education scheme at OSU, which will roll out starting in the 2021-2022 academic year.

PAR-E.07: 10:00-11:00 a.m. A Portfolio of Data Analytics Classes at University of Oklahoma

Poster – Karen M. Leighly, Homer L. Dodge Department of Physics and Astronomy, The University of Oklahoma, Norman, OK 73019

Collin Dabbieri, Alexander Kerr, The University of Oklahoma

Donald M. Terndrup The Ohio State University

We present the design and initial implementation of two data-driven Astronomy courses at the University of Oklahoma. Both courses focus on data analytics skills acquisition using the Python coding language and Jupyter notebooks, and are aimed at providing students with experiences and skills for a wide range of careers. Astronomy 3190 is a elective course for sophomores. The emphasis is on repeated exposure to the data life cycle: data wrangling, visualization, statistical thinking, modeling, computational thinking, and communication skills. Astronomy 5900 is a graduate course taken by upper-division undergraduates and graduate students. The course provides an ambitious romp through statistical inference, Markov Chain Monte Carlo, cluster analysis, regression, principal components analysis, classification, and time series. Both courses use freely available astronomical data from various sources including the Sloan Digital Sky Survey. A discussion of the learning goals and examples of specific activities will be included.

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PAR-E.07: 10:00-11:00 a.m. Application of Secondary Physics Content Through Modeling of Geoscience Data

Poster – Susan Meabh Kelly, University of Connecticut, Bridgewater, CT 06752

Public access to archived geoscience databases and open source software programs provide opportunities for students to apply and expand conventional high school physics content in new contexts. These experiences invite opportunity for original science research projects that require nothing more than a computer with an internet connection. Examples from multiple geoscience fields of study will be outlined, with a focus on students' use of computation.

PAR-E.07: 10:00-11:00 a.m. Computational Physics at Weber State University: Successes and Excuses

Invited – Daniel V. Schroeder, Weber State University, Ogden, UT 84408-2508

Weber State University is an open-enrollment commuter school where each year about 300 students take the first semester of calculus-based introductory physics, while about 10 students receive physics bachelor's degrees. We have successfully put quite a bit of computation into the curriculum for the latter group, but not for the former. In this talk I will describe some of the computational pieces in our curriculum for physics majors, including a sophomore-level scientific computing course, microcontroller programming in our electronics course, and integration of numerical approaches into some of our core theory courses. I will also offer our excuses for not making computation a significant part of the introductory course.

PAR-E.07: 10:00-11:00 a.m. Implementing and Assessing Computation Across the Curriculum at IUPUI

Poster – Andrew D. Gavrin, IUPUI, Dept. of Physics, Indianapolis, IN 46202

Yogesh Joglekar, Gautam Vemuri, IUPUI

Our goal as a department, set three years ago, is to "make computation normal." That is, our students should consider computation to be a "normal" approach to problem solving, not a special method for a few distinct classes of problems. To this end, we are on track to having approximately 25% of all assignments be computational by 2023. This talk will describe our efforts to date, with particular attention to the development of a first assessment tool and early results from its use.

PAR-E.07: 10:00-11:00 a.m. Professional Development Pathways to Integrate Computing in Physics First

Poster – Colleen Megowan Romanowicz, American Modeling Teachers Association

Rebecca Vieyra, University of Maryland

Shriram Krishnamurthi, Brown University, Bootstrap

Kathi Fisler, Brown University, Bootstrap

This poster presents an overview of an NSF-funded program to integrate Modeling Instruction for physics with Bootstrap for Algebra into Physics First courses. The program included a teacher-led developmental stage across two years, followed by a dissemination stage of three years that included 2-3 weeks of face-to-face workshops for some teachers, and a semester-long synchronous online course for others. This poster will include major program outcomes and design details, as well as reflections on essential elements for effective professional development in physics that integrates computing. Learn more about this project at https://aapt.org/K12/Computational-Modeling-in-Physics-First.cfm

PAR-E.07: 10:00-11:00 a.m. Program-level Scaffolding of Computation in Physics Curricula

Poster – Jason E. Ybarra, Bridgewater College, Bridgewater, VA 22812

We discuss integration of computation at the program level to provide students with a solid foundation in programming and the ability to transfer these skills to multiple programming languages. The success of this program depends on scaffolding throughout the curriculum, with students taking courses that introduce computation in their first two years before they reach upper-level physics. We include examples of how computational skills learned in lower-level courses lead to more advanced computational assignments in upper-level courses.

PAR-E.07: 10:00-11:00 a.m. Save the Earth: A Mechanics Thread That Introduces Computation

Poster – Michael Burns-Kaurin, Spelman College, Atlanta, GA 30314-4399

I used the thread of saving the Earth from a collision with an asteroid to introduce several concepts in mechanics. Through successive approximations to the situation, students analyze situations involving constant velocity, conservation of momentum, constant acceleration, and kinetic energy as they try to determine how best to deflect the asteroid. The tools used include computer programming with the motivation of performing computations iteratively to determine closest approach.

PAR-E.07: 10:00-11:00 a.m. Threading Computation into the Physics Curriculum at Lewis University

Invited – Ryan J. Hooper, Lewis University, Romeoville, IL 60446-2200

Heavily motivated by the 2016 AAPT Undergraduate Curriculum Task Force Report, the Physics Department at Lewis University in Romeoville, IL revised its curriculum to include more computational skills throughout. This talk will address how Lewis embeds computational components into the core curriculum as student learning outcomes with College and University wide acceptance. The dual environment model used by Lewis, which emphasizes VPython and Maple, will be articulated. An outline of the curriculum and examples of how the model is executed will be presented along with anecdotal evidence of success. Finally, the talk will describe how Lewis strives to empower educators in the Chicagoland area to enhance their curriculum with computational skill sets.

Session PAR-E.08 Physics Majors: High School to Doctorate

Tuesday, July 21, 10:00–11:00 a.m. Sponsor: AAPT

PAR-E.08: 10:00-11:00 a.m. Careers for Undergraduate Physics Majors

Contributed – Brad R. Conrad, Society of Physics Students

Physics students enter into a broad range of careers. It can be challenging to know not just what kinds of positions physics majors can apply for but how physics students can find jobs that they are well suited for. This lighthearted talk will briefly provide data round undergraduate student employment but focus on how students can find and how advisers can help undergraduates apply for positions.

PAR-E.08: 10:00-11:00 a.m. Choosing the Right Graduate Program for You

Contributed – Althea Erica Gaffney, Society of Physics Students & Sigma Pi Sigma, College Park, MD 20740

Whether it's deciding where to apply or where to matriculate, choosing between graduate programs can be stressful. This talk will share tools and tips for helping students make the best decisions around identifying graduate programs that meet their individual needs.

PAR-E.08: 10:00-11:00 a.m. Comparisons Between Physics Majors' Image of Physicists and of Themselves

Contributed – Zeynep Topdemir, Georgia State University, Atlanta, GA 30303

Brian D. Thoms, Joshua S. Von Korff, Amin Bayat Barooni, Georgia State University

Through interviews with undergraduate physics majors we have found that there is a strong correlation between their image of physicists and how they feel about themselves. Students in the earlier stage of the program stated that having knowledge is necessary to be a physicist, and they report that they don't feel like they have enough knowledge. Because of that, they stated they don't feel like a physicist. On the other hand, instead of knowledge seniors report that performing research, having physics interest, and earning a degree are necessary to be a physicist. As a result, only some senior physics majors describe themselves as a physicist. We will also compare the ideas of students with different amounts of research experience.

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PAR-E.08: 10:00-11:00 a.m. Elevate Your SPS Chapter

Contributed – Kayla D. Stephens, American Institute of Physics, College Park, MD 20740

This session will dive into strategies to help promote a vibrant SPS chapter or club. Whether you are starting a new chapter, reviving a dormant chapter or wanting to explore opportunities to elevate your current chapter activities, this talk is for you. We will focus on the motivation and engagement of your students, and how to leverage resources from a local, regional and national level in efforts to help your SPS chapter flourish.

PAR-E.08: 10:00-11:00 a.m. Sharing Physics Through Sound: Undergraduate Outreach*

Contributed – Holly Fortener, Society of Physics Students

Brad Conrad, Society of Physics Students

The Society of Physics Students is excited to continue its journey in global science outreach this summer. Science Outreach Catalyst Kits (SOCKs) are free to SPS chapters (while supplies last), and contain an exploratory physics and science activity that is specifically designed for SPS chapters to use in outreach presentations to elementary, middle, and high school students. Each SOCK comes with the essential materials to conduct a set of demonstrations, a comprehensive manual, and instructions on how to expand the demonstration to become a tried-and-true outreach activity. The 2020-21 SOCK is celebrating the international year of sound by theming its demonstrations around acoustics. Come learn about the 2020 SOCK if you are just starting out or are demo pro!

*The 2020-21 SOCK is sponsored by the Acoustical Society of America.

PAR-E.08: 10:00-11:00 a.m. The Quantum Composer: A Tool for Visualization of Quantum Phenomena

Contributed – Carrie A. Weidner, Aarhus University, Denmark

Shaeema Z. Ahmed, Jesper HM Jensen, Jacob F. Sherson, Aarhus University

Heather J. Lewandowski, JILA/University of Colorado Boulder

Researchers and educators have developed numerous tools to help students simulate and visualize aspects of quantum mechanics taught in the classroom. However, these tools are typically limited in their scope in that they focus on a narrow range of phenomena. In order to provide a more versatile tool, the ScienceAtHome group at Aarhus University has developed the Quantum Composer, a flow-based program capable of simulating 1D quantum evolution, including potentials that are not typically analytically tractable. Composer also has a suite of other tools that allow students to explore real research problems, including the simulation of Bose-Einstein condensation and control of quantum dynamics via a built-in optimizer. This presentation will introduce Quantum Composer and describe its applications in the classroom from the advanced high school level through to graduate physics education.

Session PAR-E.09 Graduate Education in US – Thinking About Admissions, Diversity, Content Knowledge, and Institutions

Tuesday, July 21, 10:00–11:00 a.m. Sponsor: Committee on Graduate Education in Physics

PAR-E.09: 10:00-11:00 a.m. "Optional" General and Physics GRE Requirements: The Impact on Prospective Graduate Students

Contributed – Lindsay M. Owens, Rochester Institute of Technology, Rochester, NY 14563

Benjamin M. Zwickl, Casey W. Miller, Rochester Institute of Technology

Graduate program's reported Physics GRE requirements, recommended minimum scores, and previous cohort score averages influence students' application decisions. In recent years, the test-optional language of No Required Minimum and GRE Optional requirements has muddied the waters for prospective applicants, particularly for women. In this qualitative study, 60 graduate students (27-F; 31-M; 2-DND) from 24 different graduate programs were asked how they decided where to (and not to) apply to graduate school. Male and female students were equally likely to apply to graduate programs that stated No Required Minimum or GRE Optional language on their admission requirements webpage. This talk will highlight how Physics GRE requirements influenced students' decisions on where to apply to graduate school and how students interpreted GRE-optional phrases when submitting their application materials. Supported by NSF-1633275

PAR-E.09: 10:00-11:00 a.m. Graduate Program Reform at the University of Utah

Contributed – Pearl Sandick, University of Utah, Salt Lake City, UT 84112-0830

Ramón Barthelemy, Jordan Gerton, University of Utah

Understanding and supporting graduate education policies and practices is critical to the success of future physicists and astronomers and to supplying well-trained science, technology, engineering and mathematics (STEM) professionals to the US workforce. As such, it is essential that graduate programs study and promote practices that support equity and inclusion. During the 2018-19 academic year, admissions into the Physics and Astronomy graduate program at the University of Utah was halted while a complete overhaul of all aspects of the program was initiated by the Department. The program reform included the recruitment and admissions process, orientation and teaching assistant training, advising practices and other student support, the curriculum, and the exam structure. This presentation will outline our process of change and highlight results from the first year of new policy implementations.

PAR-E.09: 10:00-11:00 a.m. Guided Group Work and Student Understanding in Graduate-level Physics

Invited – Christopher D. Porter, The Ohio State University, Columbus, OH 43210

Andrew F. Heckler, The Ohio State University

Guided group work (GGW) has been effectively used in undergraduate physics classrooms for years. Given the substantial selection effects between graduate and undergraduate populations, it is an open question whether group work might be useful at the graduate level. At The Ohio State University, GGW sessions have been developed and run over the past five years for each core course, but this work will focus on quantum mechanics. Students were given pretests and posttests that consist of some calculations, but mostly of conceptual questions. We will discuss trends in student performance across four years (~ 160 students), using many assessment questions covering various standard quantum mechanics content areas. We will note some prevalent misconceptions. We find a statistically significant effect of GGW attendance on student performance on related conceptual questions, even many weeks after instruction. Potential confounding effects are discussed, including student self-selection into treatment groups.

PAR-E.09: 10:00-11:00 a.m. How Do Undergraduate Institutions Matter for Physics GRE Cutoff Scores?

Contributed – Nils J. Mikkelsen, University of Oslo, Norway

Nicholas T. Young, Michigan State University

Marcos D. Caballero, Michigan State University and University of Oslo

Despite limiting access to applicants from underrepresented racial and ethnic groups, the practice of using hard or soft GRE cutoff scores in physics graduate program admissions is still a popular method for reducing the pool of applicants. The present study considers whether the undergraduate institutions of applicants have any influence on the admissions process by modelling a physics GRE cutoff score with application data from admissions offices of five Midwestern universities. Two distinct approaches based on inferential and predictive modelling are conducted. While there is some disagreement regarding the relative importance between features, the two approaches largely agree that to include institutional information significantly aids the analysis. Both models identify cases where the institutional effects are comparable to factors of known importance such as gender and undergraduate GPA. As the results are stable across many cutoff scores, we advocate against the practice of employing physics GRE cutoff scores in admissions.

PAR-E.09: 10:00-11:00 a.m. Improving the Content and Pedagogical Content Knowledge of Physics Graduate Students Using Physics Education Research

Invited – Emily Marshman, Community College of Allegheny County, Pittsburgh, PA 15212-6097

Chandralekha Singh, University of Pittsburgh

Many physics graduate students face the unique challenge of being both students and teachers concurrently. To succeed in these roles, they must develop both physics content knowledge and pedagogical content knowledge (PCK). Our research has involved improving both the content knowledge and PCK of first-year graduate students. To improve their content knowledge, we have focused on improving their conceptual understanding of materials covered in upper-level undergraduate courses since our earlier investigations suggest that many graduate students struggle with developing a conceptual understanding of quantum mechanics. Learning tools, such as the Quantum Interactive Learning Tutorials (QuILTs), have been successful, e.g., in helping graduate students improve their understanding of Dirac notation and single photon behavior in the context of a Mach-Zehnder Interferometer. In addition, we have been enhancing our semester long course focusing on the professional development of the teaching assistants (TAs) by including research-based activities. Implications of these interventions for the preparation of graduate students will be discussed.

PAR-E.09: 10:00-11:00 a.m. Review of Physics Education in USA and Indian Colleges

Contributed – Pooja Kasam, Inver Grove Heights, MN

Ramadevi Kasam, Zpss High School, Warangal, TS, India

Mallikarjunarao Kasam, Carle Foundation Hospiatal

Background: In the present paper, we are reviewing the interest statistics in the field of physics at the undergraduate level. Materials/Methods: We reviewed the data from various credible sources regarding information from the past three decades and analyzed this data. Results/Discussion: We reviewed the independent variables such as the number of students majoring in physics during their junior and senior years in their undergraduate degree. Another independent variable is examining the undergraduate graduation rate with a major in physics. In the present work, we reviewed and reported the data into 3 segments: 1975-90, 1990-2005, and 2005 – 2020. Data was collected from different reporting sources of all Indian and U.S. universities. Statistical analysis was conducted on this data and the results were discussed.

PAR-E.09: 10:00-11:00 a.m. The Physics GRE Does Not Help "Overlooked" Applicants

Contributed – Nicholas T. Young, Michigan State University, East Lansing, MI 48824

Marcos D Caballero Michigan State University, University of Oslo

One argument for keeping the physics GRE is that it can help applicants who might otherwise be missed in the admissions process stand out. In this work, we evaluate whether this claim is supported by physics graduate school admissions decisions. We used admissions data from five PhD-granting physics departments over a 2-year period to see how the fraction of applicants admitted varied based on their physics GRE scores. We compared applicants with low GPAs to ap-

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plicants with higher GPAs and applicants from large undergraduate universities to applicants from smaller undergraduate universities. We find that for applicants who might otherwise have been missed (e.g. have a low GPA or attended a small school) having a high physics GRE score did not seem to increase the applicant's chances of being admitted to the schools. However, having a low physics GRE score seemed to penalize otherwise competitive applicants.

PAR-E.09: 10:00-11:00 a.m. Using Deliberate Innovation Methodologies to Enable Graduate Student Success

Contributed – Erika E. Cowan, Georgia Institute of Technology, Atlanta, GA 30332*

Michael Schatz, Emily Alicea-Munoz, Edwin Greco, Georgia Institute of Technology

It is a given that not everyone who starts their PhD in physics will complete it. That being said, there are people who have the great potential of being competent and able researchers that leave without the PhD. Using techniques from the Georgia Tech Center for Deliberate Innovation, based in developmental psychology and behavioral economics, we are working to see more clearly what might be getting in the way of competent, motivated students who fail to complete their PhD.
*Sponsored by Dr. Emily Alicea-Munoz

PAR-E.09: 10:00-11:00 a.m. Why Physics Doctoral Students do Not Persist?

Contributed – Diana Sachmpazidi, Western Michigan University, Kalamazoo, MI 49008

Charles Henderson, Western Michigan University

Low retention rates in physics PhD programs are an unpleasant reality. There have been many efforts to study and report doctoral attrition and most studies have focused on students' attributes and mentoring relationships. However, not much work has been focused on examining the interconnection between individual attributes and departmental practices. Last year, using survey data from 19 physics graduate programs, we identified 31 students that were not intending to complete their degree. About half of these students were enrolled in two institutions. In this talk, we use survey and interview data to describe factors related to why these students did not complete their doctoral programs. For example, students who dropped out often described feeling that they did not belong in the department and that they needed to figure things out on their own. We discuss how these results can inform policymakers' decisions towards improving retention of doctoral students.

Session PAR-E.10 Recruiting, Retaining and Empowering Underrepresented Teachers in Physics Tuesday, July 21, 10:00–11:00 a.m. Sponsor: Committee on on Physics in High Schools Co-Sponsor: Committee on Teacher Preparation Presider: *Mark Hanum*

Session PS-A: Posters 1

Tuesday, July 21, 12:30–1:30 p.m. **Sponsor: AAPT**

TUESDAY

Labs/Apparatus

PS-A.01: 12:30-1:30 p.m. Challenges and Successes in Professional Development for Lab TAs

Poster – Danny Doucette, University of Pittsburgh, Pittsburgh, PA 15260

Russell Clark, Chandralekha Singhm 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.

PS-A.01: 12:30-1:30 p.m. Connecting Physics and Engineering Through a Modernization of the Advanced Physics Laboratory Curriculum*

Poster – Muriel McClendon, Chicago State University 9501 S. King Drive, WSC 309 Chicago, IL 60628-1598

John A. Peters, Mel Sabella, Austin Harton, Russell Ceballos, Chicago State University

Connecting topics, experiments and methods in Physics and Engineering through the Modernization of the Advanced Laboratory Curriculum plays a significant role in motivating student interest and addressing needs in the STEM workplace. Current STEM students must be forward-thinking to solve grand challenges and take advantage of diverse opportunities. This project focuses on traditional and modern perspectives to address science and engineering applications. This project will lead to the complete modernization of the advanced laboratory curriculum for physics and engineering students. The project has outcomes that include: 1. Outlining a curriculum plan for the modernization of CSU's applied physics/engineering laboratory with the inclusion of modern equipment, applications, and new experimental Learning Lab modules. 2. Establishing a student learning community that will inform instructional revisions by incorporating student input through the use of the Learning Assistant Program. 3. Providing outreach opportunities for increasing STEM interest by utilizing the student-developed modules at local high schools.

*Supported by the National Science Foundation (DUE# 1712389), and the Illinois Space Grant Consortium.

PS-A.01: 12:30-1:30 p.m. Designing Writing Intensive Advanced Laboratories in Physics

Poster – Sara J. Callori, California State University, San Bernardino, CA 02407

California State University San Bernardino is currently transitioning from quarters to semesters, starting in Fall 2020, with the Department of Physics transforming its curriculum. One major facet of this redesign is the creation of two writing intensive, advanced laboratory courses. These courses align with program goals and AAPT recommendations for instructional labs, including communicating physics and developing practical skills. By scaffolding assignments and creating opportunities for students to both give and receive meaningful feedback, they will be encouraged to use writing as a tool to bolster their experimental analysis by focusing on demonstrating "how they know what they know". Peer review and student-designed assessment will also help them think metacognitively about their own writing and the role of writing in the scientific process. Here, I present the course design for the new writing intensive advanced laboratories and reflect on lessons learned and changes made from the previous single-quarter course.

PS-A.01: 12:30-1:30 p.m. Distance Learning Mechanics Labs Successes and Challenges

Poster – Michael Nichols, Marquette University, Milwaukee, WI 53221-2112

Melissa Vigil, Kate Piper, Annie Carani, Marquette University

During the shift to distance learning one of the hardest parts of any physics class was how to transition labs into the remote learning environment. For our introductory course this summer, a small kit was sent out to the students containing the bare minimum for students to use as their lab supplies over the course of the mechanics semester. The kit included Lego, Binder clips, string, and a measuring tape. We will present the successes and challenges experienced using these materials to study kinematics, Newton's Laws, energy, and rotation systems. We will also discuss our goals for future refinements and expansions of this topic list.

PS-A.01: 12:30-1:30 p.m. Getting the Conversation Started: Critically Thinking About Informal Programs

Poster – Brean Elizabeth Prefontaine, Michigan State University, East Lansing, MI 48912-4147

Claire Mullen, Claudia Fracchiolla, Shane Bergin, University College Dublin

Kathleen Hinko, Michigan State University

Are you a director of an informal physics program? Do you want to think critically about how this informal environment is impacting others? Come discuss how structural elements of informal physics programs can positively impact the university students facilitating within your program. In our research, we looked at program facilitator experiences within three different informal physics programs using an operationalized version of the Communities of Practice framework to better understand how these programs support identity development. In this poster, we will do two things: 1) present the findings from our work, including the structural elements of the informal programs that support identity development, and 2) discuss the implications of these findings. We are aiming to start a discussion with practitioners about what practical applications of this research means for informal physics programs - stop by and let's get this conversation started!

PS-A.01: 12:30-1:30 p.m. How Do Students Develop Scientific Epistemologies in an ISLE-based Course?

Poster – Joshua Rutberg, Rutgers University, New Brunswick, NJ 08901

Sheehan H. Ahmed, Diane Jammula, Rutgers University - Newark

Eugenia Etkina, Rutgers University Graduate School of Education

Research[1] shows that in traditional and reformed courses students view physics experiments as confirmatory experiments for theory. They do not recognize the epistemic role of experiments as catalysts for knowledge construction. One approach to learning physics, the ISLE approach pays specific attention to the role of experiments in the construction of knowledge by the students. In the ISLE approach students encounter experiments as observational, testing and application when they construct, test and apply new ideas in a students-centered inquiry-based environment. Students learn many concepts in the course by starting to analyze experimental data. Will these experiences affect their epistemologies and help them see experiments as the sources of knowledge not only tests? Our poster provides an answer to this question using the instrument developed by Hu and Zwickl.

[1] Hu & Zwickl. Phys. Rev. Phys. Educ. Res. 14, 010121 (2018)

PS-A.01: 12:30-1:30 p.m. Implementation of Design Experiments in Large-Scale Introductory Physics Classes

Poster – Alexander J. Shvonski, Massachusetts Institute of Technology

Pushpaleela Prabakar, Jacob White, Peter Dourmashkin, 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 >700 students, with 8 sections total (~90 per section), and is built upon an "active learning" structure, where students interact with each other and online materials during class. We introduced 5 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. 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, how we integrated online components, some considerations with respect to implementation on a large scale, and also report student feedback and E-CLASS results.

PS-A.01: 12:30-1:30 p.m. Just a Draft: Improving Lab Report Writing

Poster – Mary M. Brewer Sherer, William Jewell College, Liberty, MO 64068

While improving technical writing through lab reports is a goal of most physics programs, many smaller colleges do not have dedicated lab instructors and lab development often falls to the bottom of the list. After several years of discussing (but not implementing) large scale changes in the introductory lab, we decided to focus on one small change that we could easily implement. For the first lab report of the semester, we required a draft report, which we then returned with significant comments before the final report was due. This poster discusses the results both in terms of writing and student attitudes with implementing just this one small change.

PS-A.01: 12:30-1:30 p.m. Physics Outreach at Fresno State University: A Portable Physics Demonstration Service

Poster – Eric Madrigal, California State University, Fresno, Fresno, CA 93740

John R Walkup California State University, Fresno

Don Williams California State University, Fresno

The Physics Department at California State University, Fresno has one of the most active physics outreach programs in the country. This program doubles as a service learning course for future teachers, science majors, and anyone interested in teaching. Students enrolled in this program learn many methods of teaching physics, practice their skills in performing demonstrations, and take their lessons directly into public school classrooms of all ages. Unique to this program are travel trailers, funded through a grant by Chevron, full of physics demonstration equipment for delivering physics demonstrations to school children and the overall community throughout California's Central Valley. Previous outreach students who are now teaching can borrow a fully-loaded trailer to use at their own schools, along with videos of demonstrations. An overview of this program will be presented by a pre-service teacher who recently successfully completed the program.

PS-A.01: 12:30-1:30 p.m. Using FCI Data to Develop Impactful Class Activites

Poster – Andrew E. Pawl, University of Wisconsin-Platteville, Platteville, WI 53818-3099

Careful examination of my students' individual gains on the Force Concept Inventory (FCI) led to the realization that student pretest knowledge on certain key questions appeared to be correlated to enhanced gain during the class. Acting under the hypothesis that addressing those key questions early in the course might result in broader, test-wide gains, I developed two class activities to address one of the key questions. One of the activities is a laboratory experiment and one activity utilizes a PhET simulation. I have tested those activities over the course of four semesters and there is evidence that they significantly increased the class-wide normalized gains on the FCI.

PS-A.01: 12:30-1:30 p.m. Utilizing Unity as a Classroom Tool for Physics Simulations

Poster – Kristopher A. Andrew, Lexington Montessori High School, Lexington, KY 40508

Keith Andrew, Western Kentucky University

This work details the advantages and difficulties of using the Unity development environment as a classroom tool for lab activities. The Unity software package is a cross platform highly interactive game development engine available for free by Unity, Inc. Unity gives users the ability to develop 2-d and 3-d interactive environments. We tasked a small Montessori high school classroom with completing the first tutorial on the Unity website, and we found that younger students struggled with the development environment and scripting potential. We found Unity is most useful when students have previous exposure to programming and access to online resources. Online sources provide access to a wide diversity of interesting applications which could gradually introduce students to the development environment.

PS-A.01: 12:30-1:30 p.m. Validating a Tracker-based Biomechanical Model for Undergraduate Occupational Therapists

Poster – J. Caleb Speirs, University of New England, Biddeford, ME 04005

Shannon Keavy, University of New England

Tracker Video Analysis and Modeling Tool has found myriad applications in physics classrooms and labs. A recently designed biomechanics course for future occupational therapists at the University of New England heavily utilizes this tool. In the course, students use Tracker during in-class activities as well as in personal projects to create models and study kinematics and kinesiology. The work presented in this poster describes the creation of a biomechanical model using Tracker and details the process of attempting to validate that model by comparison with data derived from 3D Motion Analysis in the University of New England Motion Analysis Laboratory (MAL).

PS-A.01: 12:30-1:30 p.m. Why Do Students Come and What Makes Them Stay?

Poster – Michele McColgan, Siena College, Department of Physics & Astronomy, Loudonville, NY 12211

Robert Colesante, Siena College, Education Department

Each year, our informal STEM program serves about sixty 5th-8th graders from a local high-needs district. We were lucky enough to work with the school district to evaluate outcomes of students in the program versus their peers. The evaluation showed that our students were outperforming their peers in standardized tests in ELA and Math while they were in the program, were graduating at high rates and had higher rates of college readiness. We also found that they were taking more advanced math and science courses in high school. But we had no idea why! After multiple online professional development courses in PER/DBER (with Rebecca Lindell of Tiliadal Solutions for Higher Ed STEM Education), the first author was able to design and execute a qualitative research study to find out. The results of the study will be presented.

TUESDAY

Lecture/Classroom

PS-A.02: 12:30-1:30 p.m. A New Model for Public Engagement Partnerships With High Schools

Poster – Michael B. Bennett, University of Colorado Boulder, CO 80309

Rosemary Wulf, Englewood High School

Noah D. Finkelstein, University of Colorado Boulder

The University of Colorado's highly successful Partnerships for Informal Science Education in the Community (PISEC) public engagement program has partnered for over 10 years with local Colorado primary schools to implement a collaborative, after-school physics learning program. In recent semesters, PISEC has complemented its work with primary schools by partnering with secondary schools in the front-range area to develop and implement project-based curricula designed to give students opportunities to engage in authentic professional scientific practice, facilitated by CU mentors. These curricula give high schoolers the opportunity to lead projects, design experiments, and present at a conference-like symposium hosted by CU Boulder. We will discuss the genesis of PISEC's high school efforts and recent outcomes, including first steps toward assessment and research.

PS-A.02: 12:30-1:30 p.m. Anticipatory Teaching Methods and Their Usage by Physics/Science Teachers

Poster – Anne E. Tabor-Morris, Georgian Court University, Lakewood, NJ 08701

When looking for good classroom practices, teachers usually consider strategies for teaching individual topics. However, in order to attain mastery, students also can benefit from fitting together topics in the broader landscape of learning. "Anticipatory teaching methods" are explored here, wherein students are alerted regarding upcoming material such that students have a sense of a goal: specifically "historical context", "vertical learning", and "quest". These methods can create a sense of anticipation, but also can encourage students to press forward in their inquiry, potentially increasing student investment. Are teachers already using anticipatory techniques and tools, even occasionally or informally? Reported here is a pilot survey of experienced high school teachers of teaching methods. Data collected indicates a drastic under-usage of anticipatory teaching methods by physics and science teachers compared to other methods, but it is an area of future research whether these methods work and/or are simply overlooked and hence under-utilized.

PS-A.02: 12:30-1:30 p.m. Anticipatory Teaching Technique of "Physics Quest" in the Classroom: Light

Poster – Anne E. Tabor-Morris, Georgian Court University, Lakewood, NJ 08701

The idea of quest as literary device is long established in the humanities community, serving to interest and propel readers. Proposed is a similar teaching technique that can assist in learning physics – specifically here in aiding student development toward understanding light. How so? When quest is used in a myth or novel it carries the reader through the adventures and growth of a character to solve a specific problem. The introduction of a "physics quest" can encourage students not only to re-inspect their own lives to find the hero within advancing toward a difficult goal, but also open the mind to the realization that several steps/topics will be needed to obtain their objective –for example the advance realization of needing to master waves, electricity, and magnetism to get to the result of the ability to fathom the nature of light – with the then added benefit of understanding diffraction and polarization.

PS-A.02: 12:30-1:30 p.m. Class of Particle Physics to Promote the Access of Girls to Scientific Education

Poster – Verania Echaide Navarro, CICATA-IPN, México

Mario Humberto Ramírez Díaz, CICATA-IPN

Nowadays, women and girls continue to be excluded from participating fully in many fields of science at national and international levels, in addition to various issues that make them distance themselves from their scientific curiosity. Physics offers a great opportunity to involve young people in science, therefore, in this article is proposed a master class of particle physics for female high school students in Mexico. The methodology of CERN and the International Group of Scope of Particle Physics (IPPOG) will be used, that way, the students can participate in a real experimental research process.

PS-A.02: 12:30-1:30 p.m. Engaging Prospective Teachers in Learning About Climate Change via Zoom

Poster – Emily H. Van Zee, Department of Physics, Oregon State University, Corvallis, OR 97330-1106

Elizabeth Gire, Department of Physics, Oregon State University

Prospective elementary teachers "met" via Zoom in a physics course during spring term. After exploring light and thermal phenomena, they considered the influence of these phenomena on global climate change. Emphasis was on understanding the greenhouse effect, interpreting evidence for rising sea levels and melting glaciers, and becoming informed about ways that individuals, communities, states, our nation, and international organizations are taking action. Both students and instructor were beginners in using Zoom. On-going revisions occurred in what to attempt with home-made materials, what to include via excerpts from our draft for an open source textbook, and what to abandon. This poster presents some of the students' written work, their reflections in ungraded surveys about their experiences during this form of remote learning, and excerpts from our open source textbook: Exploring Physical Phenomena: What happens when light from the Sun shines on the Earth?

PS-A.02: 12:30-1:30 p.m. Example Written Explanations of Qualitative Reasoning

Poster – David Liao, Bedminster, NJ 07921

Students in AP Physics 1 can sometimes have difficulty developing written explanations of qualitative reasoning, even when they are certain of their final conclusions. This poster can be printed out as a wall reference for teaching students to identify structures of reasoned arguments (using terms from Toulmin's model, McNeill's claim-evidence-reasoning (CER) model, and Frensley's ABCD model and using terms from REASoN: Relationship/rule, Equal/Same/Match, Altered/Different/Mismatch, So what?, Next?) and to provide phrasal templates for some example arguments.

PS-A.02: 12:30-1:30 p.m. Explaining Gauge Theoretical Utility Models via the Weakest Link

Poster – Daniel Young, University of North Carolina at Chapel Hill, Chapel Hill, NV 27599

Justin Hadad University of North Carolina at Chapel Hill

Gauge Theories are complex ideas often used in field theory that students are not exposed to until they have had a few years of formal training in physics. In this talk we will discuss how we introduce basic ideas behind gauge theory in an introductory course using the lens of the game show Weakest Link. Weakest Link is a game show wherein players answer questions and add money to the collective group's bank, and vote players off over time. At the end of the game one person takes all of the money deposited in the bank. The complex interactions necessary for game play necessitate an understanding and development of gauge theoretical economics, leading naturally into a small-scale discussion of gauge theories present in physics. We will present our theories behind optimal play of Weakest Link and how we connect this optimal play to an introduction to physical gauge theory.

PS-A.02: 12:30-1:30 p.m. Helping Students Understand Temperature by Using Money

Poster – Gerardo Giordano, King's College, Wilkes Barre, PA 18711-0800

Last year health issues prevented me from presenting on the continued 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 now present 3 years' worth of pretest and posttest 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.

PS-A.02: 12:30-1:30 p.m. Making Physics Problems Less Google-able

Poster – Andrew Morrison, Joliet Junior College, Joliet, IL 60431-8938

In an era when virtually every textbook homework question and test bank problem has been posted online,with solutions, how can instructors create assessments with problems that are not already online? Ideally, intructors would be able to craft assessments that develop critical physics skills without having to completely invent new problems for every type of assessment. Several possible methods of achieving this goal are described.

PS-A.02: 12:30-1:30 p.m. Presenting Physics Concepts via Head Fake Learning

Poster – Daniel Young, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599

Justin Hadad, University of North Carolina at Chapel Hill

Head-fake learning ("HFL") is a form of teaching material wherein the students do not realize the form or complexity of what they are learning. This occurs primarily when the mechanism through which the material is taught makes the students think they are learning something entirely different, i.e. how to succeed in Minute to Win It style mini-games instead of learning projectile motion. We discuss how we utilized HFL to present introductory physics and mathematical principles in a newly designed course at UNC entitled Game Show Theory, which uses game show structure and optimal play as a driving motivator. In addition, we will present examples of student work and testimonials regarding how they interacted with the course (and it's HFL methodology) and will show small-scale game show demonstrations which teach physics concepts with minimal cost.

PS-A.02: 12:30-1:30 p.m. Spiral 2.0

Poster – Kris Lui, Montgomery College, Germantown, MD 20876

Inspired by the idea of a curriculum structured by increasing complexity, I was inspired to re-design a first-year calculus-based mechanics course on this principle. In this design, students encounter four main concepts (kinematics, forces, momentum, and energy) in a 1D system, then revisit the same ideas multidimensionally, and finally in a rotational framework. In this poster, I will describe the redesigned framework and challenges and benefits of its implementation.

PS-A.02: 12:30-1:30 p.m. Student Perspective About the Impacts of Feedback

Poster – Carissa Myers, Michigan State University, East Lansing, MI 48912-4934

Rachel Henderson, Daryl McPadden, Paul Irving, Michigan State University

Projects and Practices in Physics (P-Cubed) is a flipped, problem-based learning course for introductory, calculus-based mechanics. P-Cubed was designed using the communities of practice framework, with a principle learning goal to develop scientific practices. To promote students' development of practices, students spend their in-class time working in groups of 4 to 5 members to solve complex physics problems. Practice development is then facilitated through formative feedback and assessments aligned with growth in practice. Each student receives weekly, individualized feedback from their instructor (either a faculty member, teaching assistant or learning assistant) as a practice-based assessment. The feedback focuses on helping students improve their individual understanding and group collaboration through the development of key group-based practices such as decision making and planning. This presentation reports on a series of semi-structured interviews that were conducted with students at various points in the semester to understand the impact feedback had on them.

PS-A.02: 12:30-1:30 p.m. Taking a Traditional Lecture Online– Lessons Learned

Poster – Jacqueline M. Dunn, Midwestern State University, Wichita Falls, TX 76308

As campuses were forced to move their classes online in the spring semester of 2020, many different approaches were attempted. Some faculty chose to mimic their traditional lectures exactly, meeting with students synchronously online using various formats, while others chose to move their courses online in an asynchronous format. The approach presented here utilizes a combination of the two. Along with video instructions, video lectures, lecture notes, lecture slides, discussion forums, and online labs moderated by student teaching assistants, two meetings were scheduled with students via a videoconferencing platform. Beyond the technical aspects of moving a traditional lecture from the classroom to an online environment, the analysis presented here will include methods utilized to decrease student stress and frustration with having to adjust to a new learning environment.

PS-A.02: 12:30-1:30 p.m. Themed Physics for Non-Science College Students

Poster – Kris Lui, Montgomery College, Germantown, MD 20876

Teaching physics for non-science majors is fraught with challenges. In an effort to engage this group of students, I structured the course around three everyday themes: driving, cooking, and power consumption. Further, quantitative reasoning done through graphs, rather than any equations. My poster will describe the structure and curriculum, and include some examples of student work.

PS-A.02: 12:30-1:30 p.m. Understanding the Student Experience with Emergency Remote Teaching

Poster – Bethany R. Wilcox, University of Colorado Boulder, Boulder, CO 80302

Michael Vignal, University of Colorado Boulder

In response to the COVID-19 pandemic, colleges and universities transitioned in-person instruction to a new modality we refer to as `emergency remote teaching' (ERT). As many instructors may be facing this same format in future semesters, and in response to future emergency events, it is important to understand the student experience with ERT in order to inform recommendations and best practices that can be used to improve instruction. In this manuscript, we report on preliminary findings from a survey administered to physics students to gain both qualitative and quantitative feedback on what approaches to ERT are being used as well as which were most effective at supporting student learning. Here, we four initial themes relating to: interactivity and student motivation; lecture format; exam format; and new challenges experienced by students as a result of ERT. These findings have significant implications for instructors with respect to optimizing ERT.

Lecture/Classroom II

PS-A.03: 12:30-1:30 p.m. A Large-Scale Transition to Studio-based Physics in a State University

Poster – Diego Valente, University of Connecticut, Storrs, CT 06269-3046

Sarah Trallero, Xian Wu, University of Connecticut

The University of Connecticut is currently undergoing an exciting transformation in the way introductory physics is taught in its large-scale setting. This pedagogical reform spans a total of three introductory sequences encompassing six courses in total and impacting approximately 2300 students each year. Our underlying goal was to shift away from the traditional framework of segregated lectures and laboratory sessions in favor of a studio-based instructional model blending lectures, problem-solving tutorial sessions and hands-on experimental activities. In this work we discuss details of our newly reformatted program and lessons learned in year one ed in the development stages and year one of its implementation. We also present preliminary data on concept inventory assessments administered in our reformatted courses.

PS-A.03: 12:30-1:30 p.m. Explore the Living Physics Portal: Student-centered Curricula for Interdisciplinary College Physics

Poster – Stephanie M. Williams, University of Maryland

Chandra Turpen

Adrian Madsen, Sarah B. McKagan, AAPT

Come hear about the Living Physics Portal* (www.livingphysicsportal.org), a new online environment, that supports physics faculty in finding, sharing, and adapting open-source curricular materials for interdisciplinary college physics courses. These materials can support faculty in making physics personally meaningful and coherent with students' other STEM knowledge. The Portal offers low-barrier-to-entry ways to share your own instructional materials and lets you hear about how others are using them. The Portal also supports collaboration and discussion around curricular resources. In addition to introducing the Portal, this poster will summarize: (a) the size of the curricular library, (b) the topics covered by the materials, (c) the size of the Portal community, and (d) aggregate Portal activity statistics. Come by if you want to connect with the Portal community, make a Portal account, or browse what is available through the Portal. *This work is supported by NSF #1624478 and #1624185

PS-A.03: 12:30-1:30 p.m. Guided Inquiry Physics Experiment: Perceptions and Anxiety Level of Grade 8 Students

Poster – Voltaire M. Mistades, De La Salle University, Manila, MNL 0922 Philippines

Luzette D. Oraa Bina, Bangsa Secondary School, Indonesia

A substantial body of research put forward that idea that inquiry-based laboratory is effective in closing the science process skills gap among learners. In the Philippines, however, information regarding the performance of high school learners doing a guided inquiry Physics experiment (GIPE) is limited. Using a mixed-method approach, the study looked into the perceptions and anxiety level of Grade 8 learners while engaged in a guided inquiry Physics experiment. Using an adapted scientific ability rubric to rate the level of laboratory performance of the students, their performance was correlated with their anxiety level, measured using the Physics Laboratory Anxiety Assessment Scale. The over-all anxiety level of the students was rated as intermediate and there is no clear indication that their laboratory performance is correlated with their anxiety level. Data from the students' reflective journals and interviews were analyzed qualitatively to uncover categories that emerged from the content of the individual reflections. Working as a team, supportive behavior, academic pressure, science process skills, use of language, time constraint, and readiness to high level of inquiry were found relevant to the students' laboratory performance.

PS-A.03: 12:30-1:30 p.m. Guided Problem Solving: Active Learning While Working Through Example Problems

Poster – Michelle L. Milne, St. Mary's College of Maryland, St. Mary's City, MD 20686-3001

Samantha L Elliot, St. Mary's College of Maryland

Many physics teachers work through example problems on the board in order to model problem solving while the majority of their students passively watch. However, extensive research shows that students learn more from active learning techniques than they do from passive ones. How then to convert what is often a passive, but widely-used, technique into an active and engaging one? A low-cost method is presented for working through example problems while actively engaging all students from start to finish and preliminary results on the method's effectiveness in teaching problem-solving skills are discussed.

PS-A.03: 12:30-1:30 p.m. How Can You Help Lead Instructional Change? The SEI Handbook

Poster – Stephanie Chasteen, University of Colorado, Boulder, CO 80309

Warren Code, University of British Columbia

Departments have power over their own curricula and teaching. Thus, educational change often arises at the departmental level. Faculty, instructors, postdocs, chairs, and others can be effective agents of change, supporting innovations and effective teaching practices. 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 SEI Handbook, free and online at https://pressbooks.bccampus.ca/seihandbook/.

PS-A.03: 12:30-1:30 p.m. PISEC Intercultural Camps: A Globalized Model for Informal STEM Education

Poster – Zach Mbasu, African Math Initiatives, Dublin

Claudia Fracchiolla, University College Dublin

Michael Bennett, University of Colorado Boulder

As society becomes increasingly globalised, educational physics opportunities that promote both global thinking and increased representation are critically needed for the increasing demand in STEM. To meet this need, we propose a global public engagement initiative through a series of short-term, collaborative outreach programs, facilitated simultaneously in Ireland, USA, and Kenya. These programs will take the form of one-week camps designed to expose underrepresented students in their local communities to scientific and intercultural experiences. Therefore, serving as opportunities for students and facilitators to practice scientific skills, broaden scientific horizons, have enriched learning experiences and expand scientific and cultural worldview. We will discuss what the outcomes and challenges faced through the pilot run in Kenya and what are the next steps in the development of the program.

PS-A.03: 12:30-1:30 p.m. Student Peer Evaluation in Collaborative Physics Classrooms

Poster – Laura J. Tucker, University of California, Irvine, Irvine, CA 92697-4575

A body of research supports student collaboration to increase learning and build the teamwork skills necessary for almost all careers. Yet concerns about freeloading and other behaviors can negatively affect students' learning experience. We discuss a popular strategy responding to these concerns: student peer evaluations. Peer evaluations are a course assignment in which each student evaluates each of their team members contribution to the team. We discuss the implementation of peer evaluations in large-enrollment courses and research about the relationship between peer evaluation scores and other course outcomes.

PS-A.03: 12:30-1:30 p.m. We Have Led the Horse to Water– Open Textbooks

Poster – Jennifer J. Kirkey, Douglas College, New Westminster, BC Canada

Jennifer Barker, Douglas College

The use of open textbooks in increasing dramatically in first year physics courses. This poster will present the result of scholarly research around student perceptions, the use and impact of open textbooks as well as suggestions for how instructors might change what they do in their classroom around their use of open textbooks. Comparing and contrasting student's attitudes in first year physics, astronomy and biology classes to open textbooks is the theme of this poster. It will also relate attitudes towards open educational resources (OER) to simple demographic information and the overall cost of textbooks to determine whether there are indicators that can be measured a priori to suggest that students in a particular course may be more or less receptive to the incorporation of OER. More than 300 students were surveyed in 10 courses over two years at Douglas College so there is enough data to form interesting correlations.

Physics Education Research

PS-A.04: 12:30-1:30 p.m. A Framework of Goals for Writing in Physics Lab Classes

Poster – Jessica R. Hoehn, University of Colorado, Boulder, CO 80309

H. J. Lewandowski, University of Colorado Boulder

Writing is an integral part of the process of science. In the undergraduate physics curriculum, the most common place that students engage with scientific writing is in lab classes, typically through lab notebooks, reports, and proposals. There has not been much research on why and how we include writing in physics lab classes, and instructors may incorporate writing for a variety of reasons. Through a broader study of multiweek projects in advanced lab classes, we have developed a framework for thinking about and understanding the role of writing in lab classes. This framework defines and describes the breadth of goals for incorporating writing in lab classes, and is a tool we can use to begin to understand why, and subsequently how, we teach scientific writing in physics.

PS-A.04: 12:30-1:30 p.m. Analysis of Video Explanations on Angular Momentum

Poster – Cindy Schwarz, Vassar College, Poughkeepsie, NY 12604

Sarah Ziegler, Saumya Arya, Sean Leshock, Eng Amanda, Vassar College

This study used a novel method for analyzing student understanding. Students were asked to explain angular momentum using a tablet where students' written and verbal explanations were simultaneously recorded. We then analyzed the recordings in mostly qualitative ways. Our results suggest that the method is useful in pulling out data on student confidence, gender differences and misunderstood as well as frequently mentioned topics. In general, students most commonly mentioned vector, linear momentum, and rotation. The most likely concepts to be addressed, but incorrectly explained, included the symbol for angular momentum, the equations for angular momentum, angular momentum as a cross product, and the direction of the angular momentum vector. Our determination of confidence showed men were more confident overall but there was no correlation between confidence and correctness in explanation. Knowing more about the student's cognitive processes can contribute greatly to how we teach and thereby improve student learning.

PS-A.04: 12:30-1:30 p.m. Assessing Students in Planning Investigations

Poster – Hien Khong, Kansas State University, Manhattan, KS 66502

James T. Laverty, Kansas State University

College courses are attempting to apply three-dimensional learning to both the instruction and assessment. This transformative way engages students in doing scientific practices and deepening disciplinary knowledge in physics. We used Evidence-Centered Design and the Three-Dimensional Learning Assessment Protocol to assess students' ability to engage in the scientific practice of Planning Investigations. We conducted a written exam and Think-Aloud interviews to collect data from physics students in introductory college course. We analyzed interviews using the lenses of planning theory and model-based reasoning in laboratory. The analysis helped us to identify the model of planning investigations process conducted by college students during assessment. Results from this analysis will help us interpret students' written work and support the development of assessment tasks in the future.

PS-A.04: 12:30-1:30 p.m. Development and Evaluation of a Quantum Interactive Learning Tutorial on Larmor Precession of Spin

Poster – Chandralekha Singh, University of Pittsburgh, Pittsburgh, PA 15260

Benjamin Brown, University of Pittsburgh

We conducted research on student difficulties and used it as a guide to develop, validate and evaluate a quantum interactive learning tutorial (QuILT) on Larmor precession of spin to help students learn about time-dependence of expectation values in quantum mechanics. The QuILT builds on students' prior knowledge and strives to help them develop a good knowledge structure of relevant concepts. It adapts visualization tools to help students develop intuition about these topics and focuses on helping students integrate qualitative and quantitative understanding. Here, we summarize the development, validation and in-class evaluation. We thank the National Science Foundation for support.

PS-A.04: 12:30-1:30 p.m. Development and Validation of an Interactive Learning Tutorial on Quantum Key Distribution

Poster – Chandralekha Singh, University of Pittsburgh, Pittsburgh, PA 15260

Seth T. DeVore, West Virginia University

We describe the development, validation and in-class evaluation of a Quantum Interactive Learning Tutorial (QuILT) on quantum key distribution, a context which involves an exciting application of quantum mechanics. The protocol used in the QuILT uses single photons with non-orthogonal polarization states to generate a random shared key over a public channel for encrypting and decrypting information. The QuILT strives to help upper-level undergraduate students learn quantum mechanics using a simple two state system. It actively engages students in the learning process and helps them build links between the formalism and the conceptual aspects of quantum physics without compromising the technical content. The in-class evaluation suggests that the validated QuILT is helpful in improving students' understanding of relevant concepts. We thank the National Science Foundation for support.

PS-A.04: 12:30-1:30 p.m. Development and Validation of an Interactive Tutorial on Mach-Zehnder Interferometer with Single Photons

Poster – Chandralekha Singh, University of Pittsburgh, Pittsburgh, PA 15260

Emily Marshman, Community College of Allegheny County

We developed and validated a Quantum Interactive Learning Tutorial (QuILT) on Mach-Zehnder Interferometer with single photons to expose upper-level students in quantum mechanics courses to contemporary applications. The QuILT strives to help students develop the ability to apply fundamental quantum principles to physical situations and explore differences between classical and quantum ideas. The QuILT adapts visualization tools to help students build physical intuition about quantum phenomena and focuses on helping them integrate qualitative and quantitative understandings. Findings will be presented from in-class implementation of the research-validated QuILT. We thank the National Science Foundation for support.

PS-A.04: 12:30-1:30 p.m. Emergent Explicit Group Regulation in Scientific Inquiry

Poster – Ying Cao, Drury University, Springfield, MO 65802

Pierre-Philippe Ouimet, University of Regina

In a previous project we explored video data of college freshmen engaged in small group scientific activities promoting metacognition, and developed a framework we call emergent explicit group regulation (EER). Using this construct we identify instances where students spontaneously regulate a group to move forward with an activity. In this talk, we further develop the framework by relating the effects of EER to steps in scientific inquiry, that is, observation, questioning, investigation, hypothesizing, predicting, investigating, interpreting, and communicating. We also looked at more data and identified a variety of EER. We categorized the cues that led to an EER and the effects that the EER had on the group's ability to operationalize the process of scientific inquiry.

PS-A.04: 12:30-1:30 p.m. Improvements in Representational Competencies in the Optics Lab

Poster – Catherine M. Herne, SUNY New Paltz, New Paltz, NY 12561-1135

In this study we evaluated student improvements in their representational abilities in an optics lab course based on five competency categories. The optics lab is a useful realm for representational competency, as it relies on visual observations and translation of those observations to diagrams and sketches in a laboratory notebook. Students were given regular instruction in the course on improving their representational abilities. Their laboratory notebooks were analyzed for changes over the course of a semester in five categories: depiction, symbolic representation, semantics, experimental understanding, and reflection. Overall, we observed that student representations became more complete, informational, and useful to them in their work in the class.

PS-A.04: 12:30-1:30 p.m. Just-in-Time Teaching and Peer Instruction Using Clickers in a Quantum Mechanics Course

Poster– Chandralekha Singh, University of Pittsburgh, Pittsburgh, PA 15260

Ryan Sayer, Bemidji State University

Emily Marshman, Community College of Allegheny County

Just-in-Time Teaching (JiTT) is an instructional strategy involving feedback from students on pre-lecture activities in order to design in-class activities to build on the continuing feedback from students. We investigated the effectiveness of a JiTT approach, which included in-class concept tests using clickers in an upper-division quantum mechanics course. We analyzed student performance on pre-lecture reading quizzes, in-class clicker questions answered individually, and clicker questions answered after group discussion, and compared those performances with open-ended retention quizzes administered after all instructional activities on the same concepts. In general, compared to the reading quizzes, student performance improved when individual clicker questions were posed after lectures that focused on student difficulties found via electronic feedback. The performance on the clicker questions after group discussion following individual clicker question responses also showed improvement. We discuss some possible reasons for improved performance at various stages. We thank the National Science Foundation for support.

PS-A.04: 12:30-1:30 p.m. Learning Outcomes in Simple Harmonic Motion Labs Aided by Simulations*

Poster – Emily C. Allen, The Governor's Academy - Byfield, MA 1922

Sheila Sagear, Andrew Duffy, Manher Jariwala, Boston University

Computer simulations have been used to support student learning in physics to boost conceptual understanding and make labs more widely accessible. To better understand their impact on student learning outcomes, the use of HTML5-based computer simulations for topics in mechanics were investigated in a large, algebra-based, studio physics course for life science students at a private, research-intensive institution. For the past three years, we have used an A/B testing methodology to compare learning outcomes associated with a lab activity on simple harmonic motion. Different groups in this study included students using traditional hands-on equipment only, a simulation only, or, a hybrid combination of both. We will present our findings of this study in the context of previous work and discuss the larger implications of the use of simulations in physics education.

*Funded by NSF grant DUE 1712159

PS-A.04: 12:30-1:30 p.m. Radiating Is a Verb

Poster – Andy P. Johnson, Black Hills State University, Spearfish, SD 57799

A radiation literate person understands what radiation is, where it comes from, and how it can do harm. This is a rare case in America. Students enter physics courses - and typically earn a college degree - with undifferentiated views of radioactive sources, radiation, contamination, and radiation harm. Also students also do not initially distinguish between ionizing and electromagnetic radiation. It all is one vague, bad thing - radiation. Many students talk about radiation as something like a substance or an infectious agent. Beyond a widespread lack of education, part of the problem is the noun form "radiation" which suggests the ontological category of "substance". Coming to understand particles radiating is a key step in understanding radiation in general. This talk will characterize the undifferentiated view, and propose that "radiating" is an idea to be aimed for in radiation literacy.

PS-A.04: 12:30-1:30 p.m. Understanding of Measurement Uncertainty in Transformed Laboratory Courses

Poster – River Ward, Michigan State University

Trevor Franklin, Marcos Caballero, Rachel Henderson, Michigan State University

The Michigan State University (MSU) Physics and Astronomy department has recently transformed its algebra-based introductory physics laboratory curriculum. Students enrolled in the Design, Analysis, Tools, and Apprenticeship (DATA) Lab course explore physical systems to improve their competence in laboratory practices. One of its main learning goals is to carry out experiments effectively while understanding measurement uncertainty and the limitations of an experiment. To assess students' progress toward this goal, the Physics Measurement Questionnaire (PMQ) was administered before and after instruction. Questions on the PMQ are not multiple choice but rather open ended for examining a student's thinking process. We will discuss our classification methods and overall findings from four questions on the PMQ: repeated measurements (RD), using repeated measurements (UR), same mean different spread (SMDS) and different mean same spread (DMSS). (N = 1188)

PS-A.04 12:30-1:30 p.m. One Aspect of Teaching /Learning in a Virtual Lab

Poster – Mikhail M. Agrest, The Citadel, Charleston, SC 29409-0001

It has been learned over the numerous years of teaching in a real Lab room that Recurrent Study in Labs [1,2] brings flavor and that students love it. It can be easily used in teaching Labs adjusted to a Virtual distant teaching whether the students have equipment in their hands, or they are observing the lab instructor's operating it. The author practiced it successfully teaching the cadets of The Citadel for a half of the Spring semester in five labs during COVID-19. The concept of the Recurrent Study is based on studying of the property of the event/system experimentally, then using that learned property predicting results of an event at changed conditions while keeping the property of interest non changeable. The predicted value must be checked by an experiment and the error would affect the grade. The proposed aspect was expanded from Physics to other disciplines like, Chemistry, Biology, Geology.

1. Mikhail M. Agrest, "Physics labs with flavor," *Phys. Teach.* **47** (5), 297-301 (2009). 2. Mikhail M. Agrest, "Physics labs with flavor II," *Phys. Teach*. **49** (5), 295–297 (May 2011).

Physics Education Research II

PS-A.05: 12:30-1:30 p.m. Biases, Limitations, and Focus: Student Perspectives on Subjectivity in Physics*

Poster – Randeep S. Basara, South Seattle College, Seattle, WA 98106-1499

Andrea Wooley, Leander D. Villarta, Abigail R, Daane, South Seattle College

Descriptions of the nature of science contrast the view of physics as objective, unaffected by human influence. In order to better understand students' thinking about the nature of physics, we collected responses to the question, "Do you think physics is objective or subjective?" In this presentation, we compare and contrast the ideas from "Science for All Americans" to students' ideas about the presence of subjectivity in physics. Students, prior to engaging in conversation about subjectivity, tend to describe physics without reference to human influence. After discussing this question with peers, students acknowledge the individual limitations of human perception and focus in research. We argue that an awareness about the influence of structural and individual subjectivity in classrooms can

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create a robust scientific community and disrupt the current culture that serves to marginalize groups of people.
*This material is based upon work supported by the National Science Foundation under grant no. S-STEM1643580.

PS-A.05: 12:30-1:30 p.m. Characteristics of Institutions with Learning Assistant Programs: An Equity Investigation*

Poster – Alexa N. McQuade, Department of Physics, Boston University, Boston, MA 02215

Jayson Nissen, Nissen Education Research and Design

Manher Jariwala, Department of Physics, Boston University

Learning assistant (LA) programs support instructors transforming their courses to use evidence-based instructional strategies. We investigated the types of schools that have LA programs to better understand how the distribution of those programs supports excellent and inclusive education across institutions. We used the Carnegie Classification of Institutions of Higher Education (CCIHE) public database to compare schools with and without LA programs, looking at a variety of institutional characteristics to determine whether the distribution of LA programs is equitable across different types of institutions. We will discuss the implications of our findings and identify areas for future research using critical quantitative perspectives in physics education research.
* Funded in part by NSF grant DUE 1525354.

PS-A.05: 12:30-1:30 p.m. Encouraging Collaborative Partnerships: An Extended Professional Development Process for Learning Assistants and Faculty*

Poster – Jamia Whitehorn, Chicago State University, Chicago, IL 60628

Ember Smith, Mel S. Sabella, Andrea G. Van Duzor, Chicago State University

The Learning Assistant (LA) Model involves undergraduate students as peer support in STEM classrooms. During weekly preparation sessions, faculty meet with their LAs and have the opportunity to discuss content, think about student understanding, develop instructional materials, and develop collaborative partnerships where LAs can be authentic members of an instructional team. The development of these partnerships can take time. In this poster we talk about fostering partnerships between LAs and faculty to support curriculum transformation through extended professional development, occurring over multiple semesters. Our process provides structure for an LA-faculty team to conduct and gather data through preliminary tools such as forms that guide reflection on course activities and in-class focus groups that provide direct student feedback. This extended professional development process also provides support for LA-faculty partnerships, leveraging LA expertise and supporting instructional innovation.
*Supported by the Department of Education, the National Science Foundation (DUE# 1524829), and the Illinois Space Grant Consortium

PS-A.05: 12:30-1:30 p.m. Examining and Supporting Student Construction of Alternative Lines of Reasoning*

Poster – Mikayla N. Mays, University of Maine, Orono, ME 04469

MacKenzie R. Stetzer, University of Maine

Beth A. Lindsey, Penn State Greater Allegheny

Research in physics education has shown that poor student performance on certain physics tasks may stem primarily from domain-general reasoning phenomena rather than a lack of conceptual understanding. The observed reasoning patterns are consistent with dual-process theories of reasoning (DPToR). Efforts are ongoing to design intervention strategies that can guide the development of research-based curriculum to help students strengthen their reasoning skills and support cognitive reflection. In one new intervention, students are asked to set aside (at least temporarily) their own reasoning and engage in alternative lines of reasoning. Students first respond to a qualitative physics task, then construct reasoning chains that could have been used to reach the answers given by fictitious students, and finally revisit the original physics task. In this talk, we will discuss the preliminary results, how they relate to DPToR, and the implications of our findings for future curriculum development.
*This material is based upon work supported by the National Science Foundation under Grant Nos. DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, and DUE-1821561.

PS-A.05: 12:30-1:30 p.m. Experimental Science Affect and Measurement Uncertainty

Poster – Paul R. DeStefano, Portland State University, Portland, OR 97201-0751

Physics education research (PER) has produced a large body of work from which a standard of best practices for the introductory laboratory were synthesized in the AAPT Recommendations for the Undergraduate Physics Laboratory Curriculum (2014). These guidelines emphasize teaching students to "think like a physicist". But, many introductory labs remain procedure driven and focused on data-taking. Even when they are not, students tend to believe the goal of labs is to get the "right" data from the instruments. We argue one unifying feature of the recommendations is the teaching of authentic practice and, therefore, successful lab instruction should be reflected in improved student attitudes of self-efficacy and science affect. We propose a project-based, student-centered, design-oriented learning module for first year introductory undergraduate physics labs in mechanics that emphasises experimental measurement uncertainty and is based on previously researched reforms in PER

PS-A.05: 12:30-1:30 p.m. How Do Introductory Physics and Mathematics Courses Predict Engineering Students' Performance in Subsequent Engineering Courses?

Poster – Kyle M. Whitcomb, University of Pittsburgh, Pittsburgh, PA 15260

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

Physics courses as well as chemistry and mathematics courses are considered foundational in engineering curricula and all engineering undergraduates must successfully complete courses in these subjects. However, relatively little is known about the predictive relationships between physics coursework and later engineering courses. This study uses large-scale institutional data to investigate the relationships between grades earned in foundational courses and early engineering courses in two large-population majors in order to gain insight into which foundational courses are most predictive of later performance and whether the relationship follows a linear or threshold function. Multiple regression analyses were performed on course grades using 10 years of data on 5,348 engineering students to construct a predictive model. We find that the predictive relationship between early and later performance is generally linear rather than threshold and that the strongest predictors are advanced mathematics courses along with cumulative STEM GPA, which is in turn strongly predicted by high school GPA and entry test scores. Physics and introductory engineering programming and modeling courses from the first year also predict performance in later courses. In addition, advanced mathematics courses are critical to the long-term success of engineering students in these two common majors.

PS-A.05: 12:30-1:30 p.m. Inconsistent Gender Differences in Self-Efficacy and Performance for Engineering Majors in Physics and Other Disciplines: A Cause for Alarm?

Poster – Kyle M. Whitcomb, University of Pittsburgh, Pittsburgh, PA 15260

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 different STEM disciplines. Moreover, although past research has documented self-efficacy differences between female and male students in some STEM disciplines, there has not been research comparing these relations across disciplines. In order to better understand these relations and how self-efficacy and academic performance are related, we analyzed undergraduate engineering students' physics, mathematics, engineering, and chemistry grades using large-scale institutional data and their self-reported self-efficacy using a validated survey in each of these disciplines to examine gender differences in engineering students' self-efficacy and course grades. We find discipline-dependent trends in the relationship between self-efficacy and course grades, including a self-efficacy gender gap in physics which does not close by the fourth year in engineering along with a gender gap in physics course grade that favors men despite women engineering majors outperforming men in every other discipline. The troubling trends reported here should be addressed in order to make STEM learning equitable and inclusive.

PS-A.05: 12:30-1:30 p.m. Mapping the Informal Physics Efforts in the State of Michigan

Poster – Dena Izadi, Michigan State University - East Lansing, MI 2365

Julia Willison, Kathleen Hinko, Michigan State University

We are conducting study to map the landscape of informal physics efforts using a framework we have developed based on Organizational Theory. To achieve our goals we have designed a methodology based on this framework that collects surveys and interviews with informal physics program facilitators across different states. To test our methodology, we implemented our data collection protocol across the entire state of Michigan, as a microcosm of other states in the US. Here we present data analysis for all the respondents from Michigan to create a comprehensive taxonomy of informal physics activities in our data set. In building a taxonomy, we considered different approaches for comprehensive and representative data collection.

PS-A.05: 12:30-1:30 p.m. Measuring Student Mindset Shifts in an Introductory Physics Classroom

Poster – Debbie S. Andres, Paramus High School, Paramus, NJ 07652

As teachers we are expected to incorporate various new types of instruction into our classrooms to keep up with changing standards. With each new instructional practice, we assess our students based on content and skills, but can we measure their beliefs on their ability to learn and their development of confidence? Students will step into a physics classroom with a predetermined mindset regarding their ability to learn physics or even more generally science. In my ninth grade physics classes I integrate elements of Standards Based Grading and the Investigative Science Learning Environment approach to develop physics content and science practices. I use a variety of attitudes and beliefs surveys throughout the year to track shifts in students' mindsets. Students are more actively involved in their self-reflection process. In this poster I share how my students' mindsets regarding their learning of physics have changed.

PS-A.05: 12:30-1:30 p.m. STEM Student Integration and Identity through Discipline-based Outreach Activities

Poster – Callie Austen Rethman, Texas A&M University, College Station, TX 77845

Tatiana L. Erukhimova Texas A&M University

Jonathan D. Perry, University of Texas

Beyond the formal curriculum of a physics degree, students in the field may choose to enhance their education through participation in informal experiences such as physics outreach. While participation in outreach gives students opportunities to engage with the public and communicate physics, the role of these experiences in establishing a student's identity within physics is not well understood. For the initial iteration of this study, current and former participants from outreach programs at Texas A&M University were surveyed. Results indicate a positive association between participation in physics outreach events and a student's sense of belonging within the STEM community. There are also indications of to the development of communication and teamwork skills from respondents. Interviews are currently being conducted with more in depth questions in order to get a deeper look at students' experience with outreach. With the combined results of the survey and interviews, we aim to contribute to a more complete understanding of the role of outreach in establishing a participant's identity within the field of physics.

PS-A.05: 12:30-1:30 p.m. Understanding LA Sensemaking: Are they Discussions About Physics or Teaching?

Poster – Austin C. McCauley, Texas State University

Marshall Adkins, East Carolina University,

Eleanor W. Close

Steven F. Wolf, East Carolina 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. We have been reviewing video data of LA prep sessions taken over the past three years in order to characterize LA discussions. 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 and discussions of student struggles relevant to teaching the physics content. However, we have concluded that these categories are not meaningfully distinct. We sought to understand the sensemaking LAs went through and the effect this had on group discussions. We noticed LAs tended to frame their questions as though they were potential inquiries from students or how to approach teaching the concept in class.

PS-A.05: 12:30-1:30 p.m. Understanding Motivational Characteristics of Students Who Repeat Algebra-based Introductory Physics Courses

Poster – Sonja Cwik, University of Pittsburgh, Pittsburgh, PA 15217

Yasemin Z. Kalender, 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.

PS-A.05: 12:30-1:30 p.m. Understanding Self-Efficacy and Performance of Students Who Repeat Calculus-based Introductory Physics Courses

Poster – Yangqiuting Li, University of Pittsburgh, Pittsburgh, PA 15232

Zeynep Yasemin Kalender, Christian Dieter Schunn, Timothy Nokes-Malach, Chandralekha Singh, University of Pittsburgh

College level introductory physics courses for physical science and engineering majors are often perceived as weed- out courses. These large calculus-based introductory physics courses, which are taken mainly by first-year college students at the University of Pittsburgh, act as gatekeepers for many students who want to pursue careers in physical science and engineering. Due to the societal stereotypes and biases about who belongs in physics and who has what it takes to do well in physics, many underrepresented students in these courses, e.g., women and racial and ethnic minority students, often experience stereotype threat that can cause them to perform worse than they otherwise would. Moreover, students who repeat introductory level physics courses in college due to various reasons can experience even higher level of anxiety. We conducted an investigation in which we compared the self-efficacy and performance of male and female students and students across different racial and ethnic minority groups who repeated the first calculus-based introductory physics course. These findings can be helpful in contemplating strategies to develop equitable and inclusive learning environments in these pivotal courses to help all students learn physics.

Physics Education Research III

PS-A.06: 12:30-1:30 p.m. Development of an Instrument to Measure Student Assistants' PCK-Q

Poster – Beth Thacker, Texas Tech University, Lubbock, TX 79409-1051

Jianlan Wang, Stephanie Hart, Kyle Wipfli, Texas Tech University

Student assistants (SA), including graduate and undergraduate teaching/learning assistants, are pivotal to non-traditional physics instruction in large classrooms. Despite the importance and necessity of SAs, little is known about SAs' pedagogical content knowledge (PCK) and its impact on students' learning. We are particularly interested in SA's PCK of questioning (PCK-Q) skills as that may be key to effective SA-student interaction. Our goal is to design and validate a written instrument to measure PCK-Q. Based on video analysis of SA-student interactions in an inquiry-based, introductory physics class, we are developing and validating open-ended questions for this instrument. The questions are tested on SAs, and their answers, in conjunction with analysis of their PCK-Q from video data, are used for question revision and instrument redesign. Once developed, we will use the instrument to study the impact of SAs' PCK-Q on college students' conceptual understanding of physics and critical thinking skills.

PS-A.06: 12:30-1:30 p.m. Graduate Teaching Assistant's Approach to Facilitating a Supportive Peer Network

Poster – Matthew E. Hertel, PERL at MSU, East Lansing, MI 48823

Daryl McPadden, Paul W. Irving, PERL at MSU

At Michigan State University, we have created a facilitated support network to promote the success and persistence rates of underrepresented minority students who are enrolled in Physics 183 (PHY-183) - Introductory Mechanics, a STEM gateway course. The goals of this initiative are to give students a space to build supportive peer networks and have opportunities to engage in scientific practices that support their success in physics courses. Students are invited to attend 1-2 sessions a week, that focus on helping them with physics assignments, and include a shared meal during which a planned discussion takes place. Each session is facilitated by undergraduate learning assistants (LA) and a graduate teaching assistant (TA). In this poster, we outline one TA's approach to facilitating this support network, an analysis of the TA's approach via the Communities of Practice framework, and the takeaways from studying this approach to facilitating a supportive peer network.

PS-A.06: 12:30-1:30 p.m. How Faculty Take Up Ideas from a Professional Development Program

Poster – Lydia G. Bender, Kansas State University, Manhattan, KS 66506

James T. Laverty, Kansas State University

College faculty commonly participate in professional development to learn how to improve their teaching. Typically after the program finishes there is little support for faculty to bring new teaching practices into their classrooms. By employing the Situative Perspective and Pedagogical Reasoning and Action, we investigate how faculty take up ideas from a professional development program and the factors that influence their instructional design choices. In this study we investigate a program that aims to bring Three-Dimensional Learning (3DL) into undergraduate STEM classrooms. During this program participants are tasked with creating a teachable unit that aligns with 3DL. Using interviews, fellowship recordings, and online forum responses we look at two different faculty members, Ron and Charlie, and investigate influences that impact their design of classroom materials. Moving forward, we plan to expand the case study to more participants in order to explore how these influences effect the design of professional development programs.

PS-A.06: 12:30-1:30 p.m. Investigating Teacher Growth in a Safe Professional Development Community

Poster – Michael C. Wittmann, University of Maine, Orono, ME 04469-5709

Laura A. Millay, University of Maine

In the course of a multi-year professional development program, we gathered evidence to show teacher growth in multiple types of knowledge, not limited to a deep understanding of the content and ways of reasoning with it, knowledge of what students know about a topic, and an ability to respond to their most common difficulties with the material. We believe that the focus on community development provided the foundation for individual professional development, with the community providing a safe space for teachers to engage as learners. We provide evidence that teachers felt this safety, as well as evidence of their growth in being more attentive to student ideas and using constructivist teaching strategies. We discuss the value judgments involved in our decision-making about the community and the many ways in which establishing this safe community space affected our ability to gather research data and therefore draw conclusions about our work.
*Sponsored in part by NSF grant 0962805 and 12222580.

PS-A.06: 12:30-1:30 p.m. Preparing the Next Generation of Educators

Poster – Alexandru Maries, Cincinnati, OH 45220

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, I results from over three years of implementing this program are presented, in particular, by focusing on the pedagogical practices of the GTAs.

PS-A.06: 12:30-1:30 p.m. Scaffolding Collective Reflection in a Physics Education Research Group

Poster – Robert P. Dalka, University of Maryland

Ayush Gupta, University of Maryland

Research group meetings can often function as a space for members to share their own research, receive constructive feedback, and stay informed on what others in the group are working on. This poster will introduce an activity that aims to use the PER group meeting time to reflect on the work that is being done and the values that researchers bring to their research. We will discuss how the existing group norms supported the creation and execution of this activity. The poster will discuss our reasoning and process for creating the activity and will include the activity itself. Perspectives from different participants of the activity will be shared along with how these group members interacted with the activity. Poster attendees would be invited to think together with us on how they might want to adopt/adapt the activity for their own groups.

Physics Education Research IV

PS-A.07: 12:30-1:30 p.m. "Thinking Like a Physicist" in the Middle-grades: Promising Results from 7th-grade Students Studying Magnetism

Poster – Tamara G. Young, University of Utah, Salt Lake City, UT 84112

Lauren A. Barth-Cohen, University of Utah

Sarah K. Braden, Sara Gailey, Utah State University

Significant research at the undergraduate level has been devoted to examining how students learn scientific reasoning skills, or how to "think like a physicist." Comparably, few studies in PER have focused on similar reasoning skills at the middle school level. We implemented a reform-based physics unit at the 7th grade level that is focused on supporting students in developing and refining scientific models for magnetism. Through a multiple-case study approach, we analyzed

students drawn models along with video of class discussion. Results show how 7th grade students use evidence to make arguments for and defend models of magnetism in a manner that is consistent with ways that professional physicists reason with scientific models. This is significant in light of the growing recognition of the need to support middle school students in developing scientific practices that are consistent with "thinking like a physicist."

PS-A.07: 12:30-1:30 p.m. 3 Dimensional Learning in Student Work: Developing and Using Models

Poster – Paul Bergeron, Michigan State University, East Lansing, MI 48824

The Next Generation Science Standards has laid out a vision for science instruction that mirrors the three dimensions of expert knowledge organization: Scientific Practices, Disciplinary Core Ideas, and Crosscutting Concepts. While originally devised for the K-12 classroom, increasing effort has been made to bring this philosophy to the college level. As part of our STEM gateway transformation project at Michigan State University, we've developed protocols to characterize the 3 Dimensionality of both assessment items and teaching practices. This work shifts the focus from instructor teaching to student engagement. This poster will present initial results for specifically characterizing student engagement in the Scientific Practice of Developing and Using Models.

PS-A.07: 12:30-1:30 p.m. Applying Social Network Analysis to an Online Community of Practice for Teachers

Poster – Michael Nadeau, Texas A&M University-Commerce

Bahar Modir, Robynne Lock, William G. Newton, Texas A&M University-Commerce

We take a social network analysis approach to investigate how members of an online teacher community interact with each other through a nine-week classical mechanics summer course. The class, associated with the Master program in physics with teaching emphasis at Texas A&M University-Commerce, requires students to participate in weekly problem solving and biweekly reading reflection discussion boards. We measured the weekly activity level for the community and number of interactions between students, and compared these to the average values determined for the entire semester. We found that the participation of students in problem solving discussions fluctuates from week to week; revealing the activity of the community of practice, influence of student backgrounds, and possible structural features of the course. Comparatively, the reading reflection participation did not show a noticeable variation. In order to gain more insight into our findings we characterized the types of interactions by categorizing student communication.

PS-A.07: 12:30-1:30 p.m. Comparing Attitudes of Students and Faculty About Inclusive Teaching Practices

Poster – Dan Oleynik, University of Central Florida

Jacquelyn Chini, Erin Scanlon, University of Central Florida

People inherently vary in terms of their needs, abilities, and interests. Previous research indicates that physics instructors hold negative views about people with disabilities, complicity engage in practices of ableism, and do not receive training about teaching or implementing inclusive teaching practices. However, we can support learner variability by employing inclusive teaching practices (i.e., teaching practices that support learner variation, possibly reducing though not eliminating the need for individual accommodations). Using a modified version of the Inclusive Teaching Strategies Inventory (ITSI), we surveyed 140 students and instructors from 10 APS meetings about their beliefs about and use of inclusive teaching strategies. Students and instructors both exist within the same postsecondary environment, while playing different roles. Thus, there may be similarities as well as differences in their beliefs. We will present a comparison of students' and instructors' beliefs regarding inclusive teaching practices.

PS-A.07: 12:30-1:30 p.m. Diagnosing Middle-School Students' Cognition in Argumentation Practices

Poster – Xiaoming Zhai, University of Georgia

Kevin Haudek, Michigan State University

Chris Wilson, BSCS learning sciences

Tina Cheuk, Jonathan Osborne

This study applies a cognitive diagnostic modeling approach to examine student performance on argumentation. We abstract five types of attributes which are deemed critical to successful argumentation practice: making claims, providing evidence, reasoning, justification, and deploying scientific ideas. We coded for these five attributes across 19 constructed response items for argumentation. We automatically scored responses from 932 middle school students using machine learning algorithms. We first applied many-facet Rasch analysis to classify students into different levels according to an existing learning progression of argumentation. We then examined patterns of students' mastery patterns of the five attributes within each level. Preliminary findings suggest that 36 major mastery patterns exist within the three-level learning progression. We find that the attributes of justification and reasoning are critical and challenging cognitive skills for students at lower levels of the learning progression. Some Level 3 students experience challenges using reasoning.

PS-A.07: 12:30-1:30 p.m. Does IPLS Help Students Apply Physics to Biology?

Poster – Maya Tipton, Swarthmore College, Swarthmore, PA 19081

Benjamin D. Geller, Catherine H. Crouch, Swarthmore College

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 IPLS courses better prepare life science students to use physical reasoning in contexts that extend beyond those explicitly encountered in IPLS. To answer this question of whether IPLS better prepared our students for future learning, we designed and administered a task related to fluid dynamics at the conclusion of both traditional and IPLS introductory physics courses. We describe the construction of the task and the ways in which IPLS students approached the task differently than did students in the traditional course. We interpret the results in light of the goal of the IPLS course, supporting transfer within the preparation for future learning paradigm around which our course is designed.

PS-A.07: 12:30-1:30 p.m. Exploring the Durability of Student Attitudes Toward Interdisciplinarity

Poster – Gwendolyn G. Rak, Swarthmore College, Swarthmore, PA 19081

Benjamin D. Geller, Catherine H. Crouch, Swarthmore College

Building on prior analyses of how introductory physics experiences affect student attitudes, preliminary evidence suggests that IPLS students, more so than their counterparts in traditional introductory physics courses, express the attitude that physics is relevant to their primary biological interests. We report on the durability of these attitudes. We present results from interdisciplinary attitude surveys given to students a year (or more) after their initial experience in IPLS, as well as immediately after that experience. By tracking the evolution of student attitudes over time, we assess whether attitude improvements due to IPLS are in fact stable and long-lasting. We also explore how students' subsequent coursework in biology or other disciplines may influence these attitudes.

PS-A.07: 12:30-1:30 p.m. Graduate Programs in Physics Education Research: A USA-based Survey

Poster – Mirna E. Mohamed, University of Utah, Salt Lake City, UT 84102

Ramón S. Barthelemy, University of Utah

Alexis V. Knaub, Western Michigan University

This article outlines the results of a survey seeking to understand Physics Education Research (PER) Ph.D. programs in the USA. The survey explored research group composition, the number of graduates, courses taken and more. The survey was sent to a list of PER research group leaders created by crowdsourcing from the PER community. Of the 46 PER Ph.D. programs identified and invited to the survey, 25 usable responses were received. The majority of programs were in departments of physics with fewer in schools of education or institutes of science education. Most programs required graduate physics course work, with fewer requiring research methodology courses. Only five required a course in PER. The career trajectories of students were diverse, with the majority going into academic careers. However, a robust minority pursued careers in the private sector. It is important to understand the training and support of new Ph.D.s in PER in order to train the next generation of our community leaders and sustain the field as a whole.

PS-A.07: 12:30-1:30 p.m. MAGNA: MAgnetic General kNowledge Assessment

Poster – Colleen Megowan Romanowicz, American Modeling Teachers Association

Rebecca E. Vieyra, Vieyra Software / University of Maryland

Johnson-Glenberg Mina, Arizona State University, Embodied Games, Inc.

Lopez Ramon, University of Texas at Arlington

Chrystian Vieyra Cortes, Vieyra Software

Learn about a new instrument intended to measure learners' conceptualizations of static magnetic fields, including strength and orientation, especially as they pertain to Earth's background magnetic field. The MAgnetic General kNowledge Assessment (MAGNA) was developed to measure the impact of a 3-D mobile visualization tool, MAGNA-AR, created through an NSF-funded technology development and education research project. This poster will include information about how to access and review the assessment, an opportunity to use the MAGNA-AR app, and a suggested protocol for how to help learners effectively explore fields.

PS-A.07: 12:30-1:30 p.m. Secondary Student Perspectives of Quantum Physics

Poster – Zac Patterson, The Ohio State University, Columbus, OH 43210

Lin Ding, The Ohio State University

Secondary physics curricula predominantly focus on physics content established prior to the 20th century (e.g., Newtonian mechanics, conservation of energy). Rarely are students exposed to modern physics topics (e.g., quantum mechanics, special relativity) in their formal education. Even so, students inevitably encounter terms such as “quantum” and “quantum physics” in their everyday lives. The aim of this study is to provide insight on secondary student perspectives of the terms “quantum” and “quantum physics”. While there is a body of research available that analyzes university physics majors’ perspectives of quantum physics topics, little research has been done at the secondary level. Clinical interviews of students at a Midwestern high school are conducted to establish commonalities among perspective of quantum physics topics.

PS-A.07: 12:30-1:30 p.m. SUPER Recruitment and Retention Program*

Poster – Peter A. Sheldon, Randolph College, Lynchburg, VA 24503

Sarah Sojka, Randolph College

Step Up to Physical Science and Engineering at Randolph College (SUPER) was established as a four-year recruiting and retention program in 2013 with NSF S-STEM funding. The intention is to educate the nation’s next scientists. SUPER includes a summer transition program, mentoring, study halls,a living-learning community, a four-year career plan, a common first year seminar, and research and internship experiences. The NSF funding supports need-based merit scholarships for approximately half of the students in the program. This paper examines the impact of these programs as a whole on recruitment to the College and retention to graduation with a STEM degree across a range of demographic characteristics. The goal is to determine the overall impact of a comprehensive program of student support and engagement, and as much as possible, determine how individual components of the program contribute to this impact.

*This project is supported by the National Science Foundation under Grants No. DUE-1153997 and DUE-1564970. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

PS-A.07: 12:30-1:30 p.m. The Impact of IPLS in a Senior Biology Capstone Course

Poster – Benjamin D. Geller, Swarthmore College, Swarthmore, PA 19081

Jack Rubien, Sara Hiebert Burch, Catherine H. Crouch, Swarthmore College

In this second of two paired posters exploring the longitudinal outcomes of Introductory Physics for Life Science (IPLS) on student learning, we examine whether differences in student work on a diffusion task given in the senior biology capstone course can be correlated with prior enrollment in IPLS, and how those differences reflect competencies developed in the IPLS curriculum. More specifically, we assess whether IPLS students are more likely to reason quantitatively about diffusive phenomena and to successfully coordinate between multiple representations of diffusive processes. We also use survey data to describe the attitudes toward physics of IPLS and non-IPLS students in the senior capstone, and position these findings within the broader context of our longitudinal study of the impact of IPLS on student work in later biology and chemistry environments.

PS-A.07: 12:30-1:30 p.m. Topical, Randomized Quizzes in Electromagnetism

Poster – Alexander J. Shvonski, Massachusetts Institute of Technology, Salem, MA 01970-3905

David E. Pritchard, Byron C. Drury, Yunfei Ma, 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. Finally, we sought to determine what problem variants, if any, were statistically significantly different from their counterparts within a problem. 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.

Physics Education Research V

PS-A.08: 12:30-1:30 p.m. Analogous Patterns of Student Reasoning Difficulties in Introductory Physics and Upper-Level Quantum Mechanics

Poster – Emily M. Marshman, Community College of Allegheny County, Pittsburgh, PA 15212

Chandralekha Singh. University of Pittsburgh

Very little is known about how the nature of expertise in introductory and advanced courses compares in knowledge-rich domains such as physics. We develop a framework to compare the similarities and differences between learning and patterns of student difficulties in introductory physics and quantum mechanics. Based upon our framework, we argue that the qualitative patterns of student reasoning difficulties in introductory physics bear a striking resemblance to those found for upper-level quantum mechanics. The framework can guide the design of teaching and learning tools. This work is supported by the National Science Foundation.

PS-A.08: 12:30-1:30 p.m. Analogy Models in Introductory Electricity Lessons in Austria and Germany

Poster – Thomas Schubatzky, University of Graz, Styria 8010 Austria

Claudia Haagen-Schützenhöfer, University of Graz

Jan-Philipp Burde, University of Tübingen

Thomas Wilhelm, Goethe-University Frankfurt

Introductory electricity is one of the core elements of lower secondary physics classrooms all over the world. In Austria and Germany, although there is a compulsory syllabus, teachers have a lot of freedom regarding the general structure, concepts covered and analogies they use in introductory electricity classes. This means that it is the teachers' responsibility to elementarize concepts but also to select adequate analogy models for their electricity lessons. Analogy models are seen as powerful tools for teaching abstract concepts and they can be used to explore and develop insights into phenomena which otherwise remain intangible, such as electric current. On the poster, we present different analogy models for introductory electricity which are typically used in Austria and Germany. Furthermore, we present findings from a study where we investigated how 32 teachers from Austria and Germany integrated analogy models for electric current in their teaching.

PS-A.08: 12:30-1:30 p.m. Changing the Notation that Represents a Force Changes How Students Say It

Poster – Brant E. Hinrichs, Drury University, Springfield, MO 65802

Dayna M. Swanson, Drury University

To facilitate both learning about forces and coordinating forces with the system schema, force symbols in University Modeling Instruction very carefully represent forces as detailed descriptions of interactions. For example, represents the gravitational force by Earth on a ball, where "g" represents gravitational (i.e. the type of interaction), "E" represents Earth, represents "by" and "on", and "B" represents ball. Although students are taught to say as "gravitational force", audio data from student-led whole-class discussions shows that more than 40% percent of the time was referred to as "force gravity" instead. Analogous results obtained for contact force symbols as well. Because language plays such a crucial role in learning physics, several years ago, as an experiment, the notation was changed from to to make it more closely match how it is to be read. Student use of "force gravity" and "force contact" dropped to less than 2% with this notation switch.

PS-A.08: 12:30-1:30 p.m. Developing an Interactive Tutorial on a Quantum Eraser

Poster – Emily M, Marshman, Community College of Allegheny County

Chandralekha Singh, 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. This work is sponsored by the National Science Foundation.

PS-A.08: 12:30-1:30 p.m. Development and Validation of a Sequence of Clicker Questions for Helping Students Learn Addition of Angular Momentum in Quantum Mechanics

Poster – Paul D. Justice, University of Cincinnati, Cincinnati, OH 45202-6844

Emily Marshman, Chandralekha Singh, University of Pittsburgh

Engaging students with well-designed clicker questions is one of the commonly used research- based instructional strategy 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.

PS-A.08: 12:30-1:30 p.m. Development, Validation and In-Class Evaluation of a Sequence of Clicker Questions on Larmor Precession of Spin in Quantum Mechanics

Poster – Paul D. Justice, University of Cincinnati, Cincinnati, OH 45202-6844

Emily Marshman, Chandralekha Singh, University of Pittsburgh

Engaging students with well-designed clicker questions is one of the commonly used research-based instructional strategy 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 Larmor precession of spin, 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 traditional lecture-based instruction and after engaging with the CQS.

PS-A.08: 12:30-1:30 p.m. Instructional Pragmatism: Using a Variety of Evidence-based Approaches Flexibly to Improve Student Learning

Poster – Paul D. Justice, University of Cincinnati, Cincinnati, OH 45202-6844

Emily Marshman, Chandralekha Singh, University of Pittsburgh

Instructional pragmatism is essential for successfully adopting and adapting evidence-based active engagement (EBAE) approaches in that instructors should view improving teaching and learning as a process and not get disheartened if a particular EBAE approach does not produce the desired outcome. Instructional pragmatism entails keeping a variety of EBAE methods in one's instructional toolbox and using them flexibly as needed to improve student learning and continuously refining and tweaking one's implementation of the EBAE approaches to make them effective. Here we illustrate an example of instructional pragmatism in which a quantum mechanics instructor did not give up when an EBAE method involving implementation of a sequence of clicker questions on addition of angular momentum did not yield expected learning outcomes even though it was found effective earlier. Instead, the instructor remained optimistic, viewing improving teaching and learning as a process, and pulled out another EBAE method from his tool box that did not require him to spend more time on this topic in class. In particular, the instructor created an opportunity for students to productively struggle with the same problems they had not performed well on by incentivizing them to correct their mistakes out of class. Student performance on one of the addition of angular momentum problems posed on the final exam suggests that students who corrected their mistakes benefited from the task and learned about addition of angular momentum better than those who did not correct their mistakes. Encouraging and supporting physics instructors to embrace instructional pragmatism can go a long way in helping students learn physics because it is likely to increase their persistence in using various EBAE approaches flexibly as they refine and tweak their implementation for their students. We thank the National Science Foundation for support.

PS-A.08: 12:30-1:30 p.m. Measuring Changes in Student Reasoning in Calculus-based Physics

Poster – Brianna Santangelo, Fargo, ND 58102-1352

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. We have been developing and refining a two-tiered instrument that uses screening-target methodology to disentangle student conceptual understanding from reasoning. Screening questions assess students' conceptual understanding of physics through common introductory physics problems. Target questions then require students to apply that conceptual understanding in situations that elicit intuitive, rather than formal, reasoning approaches. We administered the instrument in two calculus-based introductory physics courses during different semesters as pre- and post-tests. We will discuss how the data could be used to detect changes in various aspects of student performance and the inferences that could be drawn from these changes.

PS-A.08: 12:30-1:30 p.m. Social Positioning Correlates with Consensus Building in Two Contentious Board Meetings

Poster – Brant E. Hinrichs, Drury University, Springfield, MO 65802

David T. Brookes, California State University, Chico, CA

Jacob L. Nass, Drury university

This poster analyzes two examples of whiteboard meetings from a college calculus-based introductory physics course taught using University Modeling Instruction. In UMI, student small groups create a solution to the same problem on 2? × 3? whiteboards. They then sit in a large circle with whiteboards held facing in and conduct a student-led whole-class discussion to reach consensus. In the first example students overcame sharp disagreements to reach consensus, but in the second example they don't. We examine how social positioning contributed to students either successfully examining and resolving different ideas or failing to do so. Results from these two examples support the idea that meetings where "experts" soften their position by "hedging" more frequently are better able to overcome sharp initial disagreements to reach consensus on their own. Our analysis suggests that the way students position themselves in discussions may open or close the collaborative space to productive sense-making.

PS-A.08: 12:30-1:30 p.m. Student Difficulties with Operators Corresponding to Observables in Dirac Notation

Poster – Emily M. Marshman, Community College of Allegheny County

Chandralekha Singh, 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 analysis of data on the common difficulties found. We thank the National Science Foundation for support.

PS-A.08: 12:30-1:30 p.m. Success or Failure in Intro Physics – Which Factors Matter Most?

Poster – Duane L. Deardorff, The University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3255

Many students struggle to succeed in their introductory physics courses. At UNC-Chapel Hill, we transformed our courses to make them more student-centered with greater emphasis on active learning. Our primary goal was to improve student learning, but we also hoped that these courses would be more equitable across different demographics. We also hoped that fewer students would fail or drop out of these courses. Now that these courses have been operating for approximately five years, we have enough data to see what factors most influence students' success or failure in these courses.

Technologies

PS-A.09: 12:30-1:30 p.m. A Simple Determination of Planck's Constant with a Smartphone

Poster – Martín Monteiro, Universidad ORT Uruguay

In this work we propose a simple experiment with thermal radiation to analyze Planck's radiation law, that allows us to obtain an accurate value of Planck's constant. A tungsten filament bulb is used as a source of thermal radiation. The temperature of the filament is changed using a variable DC supply. By means of a voltmeter and an ammeter, the resistance of the filament is obtained and hence, its temperature. The intensity of the light emitted by the bulb is measured by the ambient light sensor of a smartphone. Thanks to the narrow spectral response of this sensor, a relationship between temperature and spectral radiance for a fixed frequency is obtained, which is in good agreement with Planck's law.

PS-A.09: 12:30-1:30 p.m. Affordances and Strategies for Teaching introductory Circuits to Blind Children

Poster – Dan MacIsaac, Buffalo State College, Buffalo, NY 14222-1095

Kathleen Falconer, Universität zu Köln

Manuela Welzel-Breuer, Pädagogische Hochschule Heidelberg University of Education

Pamela Detrois, Staatliche Schule für Blinde und Sehbehinderte

We describe affordances – simple modifications to equipment and procedures, and interventions for teaching an introductory lesson showing the classic one bulb in a circuit, two bulbs in series, then two in parallel sequence. Affordances for partially sighted, visually impaired students are straightforward, with slight but important adaptations to apparatus, lesson flow and timing. Affordances for profoundly blind students include using circuit representations on raised plastic or paper (swell paper) with and without Braille, and rigidly supported concrete circuits created with "Snap Circuits" TM apparatus. Given a second or two for thermal stabilization, sightless students can discriminate by touch between dark, partially lit and brightly lit incandescent sub-miniature bulbs for the traditional comparisons. We also discuss the need to establish trust and safety for blind children in handling simple circuit elements.

PS-A.09: 12:30-1:30 p.m. PICUP: The Partnership for Integration of Computation into Undergraduate Physics

Poster – Larry Engelhardt, Francis Marion University, Florence, SC 29506

Danny Caballero, Michigan State University

Marie Lopez del Peurto, University of St. Thomas

Kelly Roos, Bradley University

Bob Hilborn, AAPT

We will provide an update on the status of "PICUP" the "Partnership for Integration of Computation into Undergraduate Physics". This will include the growth of the PICUP community (of physics teachers like yourself), as well as the resources that PICUP has to offer you. This work is funded by the National Science Foundation under DUE IUSE grants 1524128, 1524493, 1524963, 1525062, and 1525525.

TUESDAY

PS-A.09: 12:30-1:30 p.m. Student Learning Outcomes with Hybrid Computer Simulations and Hands-On Labs*

Poster – Sheila Sagear, Departments of Astronomy and Physics, Boston University, Boston, MA 02215

Emily Allen, Science Department, The Governor's Academy

Manher Jariwala, Andrew Duffy, Department of Physics, Boston University

Computer simulations for physics labs may be combined with hands-on lab equipment to boost student understanding and make labs more accessible. Hybrid labs of HTML5-based computer simulations and hands-on lab equipment for topics in mechanics were investigated in a large, algebra-based, studio physics course for life science students at a private, research-intensive institution. Computer simulations were combined with hands-on equipment and compared to traditional hands-on labs alone using an A/B testing protocol. Learning outcomes were measured for the specific topic of momentum conservation by comparing student scores on post-lab exercises, related quiz and exam questions, and a subset of questions on the Energy and Momentum Conceptual Survey (EMCS) administered before and after instruction for both groups. We will present our findings of this study in the context of previous work and discuss the larger implications of the use of simulations in physics education. *Funded by NSF grant DUE 1712159.

PS-A.09: 12:30-1:30 p.m. Teaching 3D Physics Concepts with Augmented Reality

Poster – Nick M. Giordano, Siena College, Albany, NY 12211

Michele McColgan, Graziano Vernizzi, Siena College

Students find difficulty visualizing 3D concepts in our physics courses. In our introductory calculus-based physics and upper-level electricity and magnetism courses, students struggle to visualize electric and magnetic fields, electric flux, Gauss's law, electromagnetic induction, three-dimensional integration, and the divergence theorem, to name a few of the E&M topics that are well suited for visualization using augmented reality. For example, when teaching Gauss's law, the mathematical formalism tends to hide the geometrical meaning of Gauss's law, more than explain it. Therefore, an AR hands-on visual representation can greatly help in rendering the concepts of flux through a surface or charge density in a given volume, so as to help students understand the physics behind it. In this poster presentation, we will demonstrate the AR applications and activities that we've developed and plan to use in our courses.

PS-A.09: 12:30-1:30 p.m. Teaching a Blended Course with TopHat*

Poster – Andrew G. Duffy, Boston University, Boston, MA 02215

TopHat is a platform known for in-class quizzing, with students using their phones to respond to questions. However, in our two-semester introductory algebra-based physics sequence, we are leveraging the TopHat platform to do significantly more than that. In addition to the in-class clicker feature, we are using TopHat for (1) pre-class preparation, with quizzes that include videos, content, and feedback from the students to the instructor; (2) online homework; (3) quizzes that are automatically graded; (4) an interactive e-book, with a significant number of embedded simulations. In this talk, I will provide some details about these four different uses, and show examples of each. The vast majority of the material we use was created by us, with a goal of making high-quality content available to the students for a reasonable cost.

*Funded by NSF grant DUE 1712159.

PS-A.09: 12:30-1:30 p.m. Teaching Elementary School Teachers How to Teach Math and Science

Poster – Jennifer J. Kirkey, Douglas College, New Westminster, BC Canada

The MSTE or Mathematics and Science Teaching Graduate Diploma is for working elementary or middle-school teachers. Designed to help teachers get comfortable with the new mathematics curriculum, rediscover chemistry, biology, physics and earth science and connect with other teachers in a positive and friendly environment. This poster will present the lessons learned from the four cohorts that have been offered at Douglas College, New Westminster, British Columbia, Canada. https://www.douglascollege.ca/programs-courses/catalogue/programs/PDMSCT This is one of the few programs of its type in Canada. This poster will present the lessons learned when science teachers work with teachers who have been working in their field for years. The program is offered in a hybrid format, so this poster will also highlight ways to connect with elementary school teachers in an online format.

PS-A.09: 12:30-1:30 p.m. Teaching Introductory Physics Courses with Interactive Activities & Personalized Support

Poster – Priya Jamkhedkar, Portland State University

Ralf Widenhorn, Theodore Stenmark, Chuck Faber, Misty Hamideh, Toai Nguyen, Portland State University

This poster summarizes the development of interactive courses with personalized support for algebra-based and calculus-based introductory physics courses taught at Portland State University. Teaching introductory physics courses to large classes with students with diverse skills in math, problem-solving, conceptual reasoning, and learning preferences is challenging. Providing interactive activities such as simulations, concept questions and problems with scaffolding questions along with support for students with different learning preferences and skill levels has the potential to promote active and engaged learning to have a long-lasting impact on the students' educational experience. We conclude the poster with early results and insights for the future improvements to these courses.

PS-A.09: 12:30-1:30 p.m. The Smartphone as a Hydrophone

Poster – Martín Monteiro, Universidad ORT Uruguay

Arturo C. Martí, Faculta de Ciencias, Universidad de la República

Several models of smartphones are currently submersible, and the performance of their microphones underwater is good enough to be used as true hydrophones capable of conducting physics experiments. A very elementary application of the hydrophone, suitable for a basic physics course, is to use it to determine the speed of sound in water. Here we present two related activities, one is to measure the speed of sound in water from the time difference of two signals and the speed of sound in air. The other problem-activity consists in determining the distance of a sound source from the delay between two signals, one that travels through the air and another that travels through the water.

PS-A.09: 12:30-1:30 p.m. Visualizing Differences in Simple Circuits Using a Computer Simulation

Poster – Jan-Philipp Burde, University of Tübingen Auf der Morgenstelle, Germany

Arthur Kronenberger, University of Salzburg

Understanding the basic concepts of electricity represents a major challenge to most students in K-12 education. In particular, most learners do not succeed in developing a robust understanding of potential and potential difference and instead tend to reason exclusively with current and resistance. These conceptual difficulties can be partly explained by the fact that potential differences cannot directly be perceived and are hence hard to imagine for students. To make potential differences and electric circuits in general more accessible to students, a new interactive computer simulation was developed. One of its key features is not only that any simple circuit can be simulated, but that it also supports different model representations of potential differences (e.g. a water flow model). On the poster, we will discuss the advantages and disadvantages of the different model representations from a PER perspective and highlight some of the features of the freely available simulation.

Session PAR-F.01-PAN Broadening Participation in STEM through Science Cafes and Festivals

Tuesday, July 21, 2:30–3:30 p.m. **Sponsor: Committee on Science Education for the Public**

The scientific literacy of the general population can be improved through engagement in public science events. From small scale science cafes to large city-wide festivals, the panelists in this session will describe the challenges and successes of increasing STEM participation through public outreach events.

Speakers:

Tatiana Erukhimova, Texas A&M University

Richard Gelderman, Western Kentucky University

Shannon Willoughby, Montana State University

Ben Wiehe, MIT Museum

Session PAR-F.02 Communicating Sensitive Topics in the Classroom

Tuesday, July 21, 2:30–3:30 p.m. **Sponsor: Committee on Physics in Two-Year Colleges Co-Sponsor: Committee on Women in Physics**

PAR-F.02: 2:30-3:30 p.m. Talking About Genders in the Classroom

Invited – Jennifer Blue, Miami University, Oxford, OH 45056

Adrienne Traxler, Wright State University

Gender can be a touchy subject in any classroom, and perhaps it seems even more so in physics, where many women and LGBTQIA+ people have traditionally felt unwelcome. This talk will start with information about the status quo for these groups. Then it will provide advice and resources to help physics teachers as we work towards making everyone feel welcome in our classrooms, at our schools, and in our workplaces.

PAR-F.02: 2:30-3:30 p.m. Tough Topics – Stepping Outside the Comfort Zone

Invited – Pearl Sandick, University of Utah, Salt Lake City, UT 84112-0830

In our roles as instructors and mentors, we are responsible, at a minimum, for training our students to be competent scientists and colleagues. We are also responsible for maintaining a respectful, positive, and inclusive classroom environment that is conducive to learning for all students. It can be necessary, from time to time, to discuss issues of gender, race, and identity, and to lead productive conversations about these topics with our students. In the course of my career, I have increasingly embraced these conversations as teaching and learning moments. Here, I will discuss some examples of leading students into what can be uncomfortable territory, what I've learned on these excursions, and the benefits of such discussions in the classroom and beyond.

Session PAR-F.03 Frontiers of Astronomy

Tuesday, July 21, 2:30–3:30 p.m. **Sponsor: Committee on Space Science and Astronomy** **Presider:** *Emily Welch*

PAR-F.03: 2:30-3:30 p.m. Astrobiology: Formation and Processing of Amino Acids in Space*

Invited – Michael Famiano, Western Michigan University, Kalamazoo, MI 49008-5252

Richard Boyd, The Ohio State University

Toshitaka Kajino, National Astronomical Observatory of Japan

Takashi Onaka, University of Tokyo

Yirong Mo, Western Michigan University

The discovery of bio-molecules in meteorites with an excess of one chiral state has created one of the biggest questions in science today. That is, what is the origin of bio-molecular homochirality? Studies of this question are highly interdisciplinary, and while several phenomenological models exist, we examine the relationship between fundamental symmetries at the particle level and the macroscopic formation of bio-molecules. A model has been developed which couples fundamental interactions with the formation of molecular chirality. In this magneto-chiral model atomic nuclei bound in amino acids interact via the weak interaction in stellar environments. Nuclei are coupled to the molecular geometry (chirality) via the shielding tensor – the same interaction responsible for NMR identification. Interactions with leptons can then selectively destroy one chiral state over the other. Possible sites are proposed in which this model may exist. It may be possible to test the formation of chiral bio-molecules in space in a polarized electron beam experiment. Such an experiment will be discussed along with several problems and questions associated with it.

*Funded by the Moore Foundation, a Western Michigan University FRACAA grant, and a visiting professorship at the National Astronomical Observatory of Japan.

PAR-F.03: 2:30-3:30 p.m. The Hunt for (Almost) Dark Galaxies

Invited – Lukas Leisman, Valparaiso University, Valparaiso, IN 46383*

Are there galaxies that we can't see? The ALFALFA survey uses Arecibo Observatory, the largest fully functional radio telescope in the world, to search for (nearly) starless galaxies that emit radio waves. This talk will summarize the field of galaxy formation and evolution, present results from ALFALFA, and explore what these results tell us about how galaxies form. A special emphasis will be given to the contributions of student researchers to this work.

*Sponsored by Kevin Lee

Session PAR-F.03B Innovations in Teaching Space Science and Astronomy

Tuesday, July 21, 2:30–3:30 p.m. **Sponsor: Committee on Space Science and Astronomy**

PAR-F.03B: 2:30-3:30 p.m. Scaffolds to Support Student Learning: Judging Astronomical Explanations

Invited – Janelle M. Bailey, Temple University, Dept. of Teaching & Learning, Philadelphia, PA 19122

Doug Lombardi, University of Maryland

Timothy G. Klavon, Archana Dobaria, Temple University

Critique and evaluation of scientific explanations has been underemphasized in K-12 science classrooms (NRC, 2012), and as a result, college students may still need assistance in learning how to make such evaluations about astronomy concepts. The Model-Evidence Link (MEL) diagram is an instructional scaffold that promotes students to critically evaluate alternative explanations and increase their ability to understand complex scientific concepts. Relatedly, the build-a-MEL (baMEL) allows student agency in selecting from provided choices to make and use a new MEL diagram. We have created two astronomy-related activities: a MEL about the Moon's formation and a baMEL on the origins of the Universe. Research on student learning about the Moon's formation and about the Universe's origins, as well as on students' ability to be critically evaluative, is ongoing. These activities are NSF-sponsored and freely available to instructors. The activities are appropriate for undergraduate non-science majors, future teachers, and high school students.

PAR-F.03B: 2:30-3:30 p.m. Space Science, Physics Education, and the NASA/AAPT Collaboration

Invited – Ramon Lopez, The University of Texas at Arlington, TX 76019

All industrialized countries are facing the same problem of declining student interest in pursuing STEM careers. In physics education, the typical response is to examine issues of appropriate and effective pedagogy, as well as gender and cultural inclusion (both in and out of the classroom). While it is appropriate that the physics community examine what it can do to make physics education more accessible to a greater diversity of students, there are some boundary conditions concerning student interest and motivation that need to be considered in parallel. In this presentation I will examine some issues related to student interest in science, and how the broad student interest in space science can be leveraged to recruit and especially retain students in STEM majors. NASA has established a National Space Science Education center that is partnering with AAPT to capitalize on the leverage that student interest in space science provides. I will present the current status of the effort, plus outline how the AAPT team is launching a project to create a network of space science educators in 2-yr colleges, in collaboration with NASA's Space Grant program.

PAR-F.03B: 2:30-3:30 p.m. Undergraduate Astronomy Majors: Curriculum Topics, Approaches, and Needs

Invited – Kimberly Coble, San Francisco State University, San Francisco, CA 94132-1740

Janelle M. Bailey, Temple University

Colin Wallace, University of North Carolina, Chapel Hill

Rica French, Mira Costa College

Karen Masters, Haverford College

Edward Prather, University of Arizona

The field of astronomy education research has made great strides in basic research, assessment, and development of active learning materials for general education ("ASTRO 101") courses. However, very little has been done in the realm of astronomy majors. We have been working with the American Astronomical Society's Education Committee to create a survey and hold forum discussions for instructors interested in the undergraduate majors' curriculum to identify current topics, practices and needs. We report preliminary results and invite members of the AAPT community to provide input. Our eventual goal is to use this information to strategically guide research and curriculum development for undergraduate astronomy majors.

Session PAR-F.05 PER Curriculum and Instruction III

Tuesday, July 21, 2:30–3:30 p.m. Sponsor: AAPT

PAR-F.05: 2:30-3:30 p.m. Characterizing Active Learning Environments in Physics Using COPUS

Contributed – Kelley Commeford, Drexel University, Annandale, NJ 08801

Eric Brewe, Drexel University

Adrienne Traxler, Wright State University

Active learning has been shown to be more effective than passive lecture methods, but more work must be done to understand what mechanisms lead to effective active learning environments. The first step in understanding the mechanisms of active learning pedagogies is to establish a vocabulary with which to characterize them. One such method we have used is the Classroom Observation Protocol for Undergraduate STEM (COPUS), which codes student and instructor activities in two minute intervals. These profiles give us a picture of what kinds of activities are occurring in the classroom with the implementation of a given pedagogy. We have gathered COPUS profiles for six active learning pedagogies in physics. We discuss the individual characteristics for each pedagogy and present results from latent profile analyses.

PAR-F.05: 2:30-3:30 p.m. Daily Bell Ringers: Short Activities Impacting Science Identity, Pedagogical Knowledge, and Students' Science Attitudes

Contributed – Steven J. Maier, Northwestern Oklahoma State University, Alva, OK 73717-2799

Can regular, short, beginning of class activities (ie "Bell Ringers") favorably impact students' science identity, pedagogical knowledge, and attitudes toward science? These types of activities are supposed to engage learners at the very start of the class, getting them on task and settled from the hallway. As this is an instructional strategy common in K-12 learning environments, their effectiveness and utility among pre-service teachers merits investigation. Firstly, treating pre-service teachers more as adult learners, these activities could be "make and take" mini lessons for teacher candidates to collect for use in their own classrooms. Secondly, though seemingly unrelated at first, the "lessons" to be learned in these activities could further build upon or augment course curriculum in subtle yet measurable ways. In this talk, I will briefly explore how these types of activities could serve other roles while presenting initial findings investigating their effectiveness.

PAR-F.05: 2:30-3:30 p.m. Does IPLS Help Students Apply Physics to Biology?

Contributed – Maya Tipton, Swarthmore College, Swarthmore, PA 19081

Benjamin D. Geller, Catherine H. Crouch, Swarthmore College

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 IPLS courses better prepare life science students to use physical reasoning in contexts that extend beyond those explicitly encountered in IPLS. To answer this question of whether IPLS better prepared our students for future learning, we designed and administered a task related to fluid dynamics at the conclusion of both traditional and IPLS introductory physics courses. We describe the construction of the task and the ways in which IPLS students approached the task differently than did students in the traditional course. We interpret the results in light of the goal of the IPLS course, supporting transfer within the preparation for future learning paradigm around which our course is designed.

PAR-F.05: 2:30-3:30 p.m. Harnessing Active Learning in Educational Videos

Contributed – Gregory Kestin, Harvard University, Cambridge, MA 02138

Kelly Miller, Harvard University

The recent global move to online instruction has increased the importance of videos in education. At the same time, active learning has become increasingly accepted as an improvement over passive instruction. How can we transfer the advantages of active learning to instruction via video? We found that physics videos are most effective when they are designed both to actively engage students and manage their cognitive load. Notably, it is the combination that matters; videos that either solely promote active learning or solely manage cognitive load provide no advantage to learning outcomes.

PAR-F.05: 2:30-3:30 p.m. Temporal Patterns of Students Using Online STEM Skills Practice Assignments

Contributed – Megan Nicole Nieberding, The Ohio State University, Columbus, OH 43210

Andrew Heckler, The Ohio State University

"Essential Skills" is an online skills practice application assigned weekly to students to improve their fluency in the basic STEM skills necessary for solving more complex physics problems. We have investigated the temporal patterns of over 1500 algebra and calculus physics students practicing multiple topics, several times each, throughout the semester. We report an observed increase in student accuracy and a decrease in response time per question for the vast majority of the topics. We will characterize the progression of student response times and accuracies as they revisit the topics though out the semester, including observations of patterns relating the accuracy and time evolution data to student grades in the course. Additionally, we will comment on the comparisons between the two groups of students (algebra vs calculus physics students) in terms of their accuracies and response time throughout the practice.

PAR-F.05: 2:30-3:30 p.m. The Impact of IPLS in a Senior Biology Capstone Course

Contributed – Jack D. Rubien, Swarthmore College, Swarthmore, PA 19081

Sara Hiebert Burch, Catherine H. Crouch, Benjamin D. Geller, Swarthmore College

In this second of two paired talks exploring the longitudinal outcomes of Introductory Physics for Life Science (IPLS) on student learning, we examine whether differences in student work on a diffusion task given in the senior biology capstone course can be correlated with prior enrollment in IPLS, and how those differences reflect competencies developed in the IPLS curriculum. More specifically, we assess whether IPLS students are more likely to reason quantitatively about diffusive phenomena and to successfully coordinate between multiple representations of diffusive processes. We also use survey data to describe the attitudes toward physics of IPLS and non-IPLS students in the senior capstone, and position these findings within the broader context of our longitudinal study of the impact of IPLS on student work in later biology and chemistry environments.

PAR-F.05: 2:30-3:30 p.m. Understanding the Student Experience with Emergency Remote Teaching

Contributed – Bethany R. Wilcox, University of Colorado Boulder, Boulder, CO 80302

Michael Vignal, University of Colorado Boulder

In response to the COVID-19 pandemic, colleges and universities transitioned in-person instruction to a new modality we refer to as `emergency remote teaching' (ERT). As many instructors may be facing this same format in future semesters, and in response to future emergency events, it is important to understand the student experience with ERT in order to inform recommendations and best practices that can be used to improve instruction. In this manuscript, we report on preliminary findings from a survey administered to physics students to gain both qualitative and quantitative feedback on what approaches to ERT are being used as well as which were most effective at supporting student learning. Here, we four initial themes relating to: interactivity and student motivation; lecture format; exam format; and new challenges experienced by students as a result of ERT. These findings have significant implications for instructors with respect to optimizing ERT.

TUESDAY

TUESDAY

PAR-F.06: 2:30-3:30 p.m. "Guiding Star" Principles to Organize Change Efforts: The TRESTLE Network*

Contributed – Stephanie Chasteen, University of Colorado Boulder, Boulder, CO 80809

In 2015, seven institutions joined forces to apply a common model of change, creating the Transforming Education, Stimulating Teaching and Learning Excellence (TRESTLE; http://trestlenetwork.org) network. In this talk I will discuss how we are using "principles" to evaluate the network and its impacts (see M.Q. Patton, 2017). Principles are statements which identify the core values, philosophy, or operating assumptions of an initiative, allowing a project to externalize its core values and create accountability for enacting those values. For example, one core principle of TRESTLE is "focus on the department as the main unit of change." Identifying the core principles of TRESTLE allows us to ask questions such as "Has the network adhered to its principles?", "How were the principles adapted?", "Are these principles effective?", and "How do these principles appear differently at different levels of the system?"

*This material is based upon work supported by the National Science Foundation under Grant No. 1525331

PAR-F.06: 2:30-3:30 p.m. A Refined Model for Characterizing Pedagogy in Informal Learning Environments

Contributed – Michael B. Bennett, University of Colorado Boulder, Boulder, CO 80809

Noah D. Finkelstein, University of Colorado Boulder

Compared to pedagogy in formal settings, comparatively little work has been done investigating techniques of pedagogy in informal learning environments. A 2016 study [1] addressed this issue, developing an observation-based model characterizing the pedagogical modes of volunteer instructors in an afterschool informal education program. Following the methodology of that study, we have observed and analyzed instructor pedagogy in a University of Colorado Boulder-based informal physics education program. The result is a model that both corroborates and expands upon the results of the 2016 study, more clearly accounting, e.g., for instructors' varying objectives in the informal learning environment. We will describe study methodology and results, discuss the expanded model, and address application of the model in other informal learning environments.

[1] Hinko et al., Phys. Rev. Phys. Educ. Res. 12, 010111 (2016)

PAR-F.06: 2:30-3:30 p.m. Explore Your Assessment Data with PhysPort

Contributed – Eleanor C. Sayre, Kansas State University, Manhattan, KS 66506

Sarah B. McKagan, American Association of Physics Teachers

Adrian M Madsen

PhysPort (www.physport.org) has hundreds of free, evidence-based, and friendly resources for teaching physics. In this talk, I'll outline how PhysPort can help you choose research-based assessments (like the FCI, BEMA, or CLASS), collect data in your classes, and make sense of what your data tell you. The PhysPort Data Explorer has a beautiful, intuitive interface to help you understand how groups of students are learning, track your teaching over time, and include useful information in your annual review, promotion, and tenure documents. The Data Explorer can handle your old spreadsheets of past data, too.

PAR-F.06: 2:30-3:30 p.m. How Faculty Take Up Ideas from a Professional Development Program

Contributed – Lydia G. Bender, Kansas State University, Manhattan, KS 66502-4160

James T. Laverty, Kansas State University

College faculty commonly participate in professional development to learn how to improve their teaching. Typically after the program finishes there is little support for faculty to bring new teaching practices into their classrooms. By employing the Situative Perspective and Pedagogical Reasoning and Action, we investigate how faculty take up ideas from a professional development program and the factors that influence their instructional design choices. In this study we investigate a program that aims to bring Three-Dimensional Learning (3DL) into undergraduate STEM classrooms. During this program participants are tasked with creating a teachable unit that aligns with 3DL. Using interviews, fellowship recordings, and online forum responses we look at two different faculty members, Ron and Charlie, and investigate influences that impact their design of classroom materials. Moving forward, we plan to expand the case study to more participants in order to explore how these influences effect the design of professional development programs.

PAR-F.06: 2:30-3:30 p.m. Improving Education Through Departmental Change: A Comparison of Approaches

Contributed – Alanna Pawlak, University of Colorado Boulder, Boulder, CO 80309

Sarah E. Andrews, Dena F. Rezaei, Joel C. Corbo, Noah D. Finkelstein, University of Colorado Boulder

Those seeking to change the policies, practices, and cultures of universities to support effective educational practices often find it a challenge. To navigate this work, change efforts are increasingly being focused at the department-level, including two models for departmentally-based change: the Departmental Action Team (DAT) Project and Teaching Quality Framework (TQF) Initiative. In the DAT Project, externally-facilitated working groups, comprised of students, faculty, and staff, pursue collectively-determined projects aimed at improving the undergraduate experience in their department. In the TQF Initiative, externally-facilitated working groups of faculty (modeled on the DAT Project) focus on transforming teaching evaluation practices in their department. To better understand these related models of institutional change, we conducted interviews with individuals from the DAT Project and TQF Initiative, including facilitators and grant PIs. We present results that give insight into outcomes of these models, impacts of differences between the models, and avenues for growth in the models.

PAR-F.06: 2:30-3:30 p.m. Improving High-School Physics Lessons Through Action Research

Contributed – Sachiko Tosa, Niigata University, Niigata, 950-2181 Japan

The use of active-learning instructional strategies in high schools is strongly emphasized in the new Course of Study in Japan. However, in the actual classroom, one-way didactic teaching is more common. This study focuses on a high-school physics teacher and examines how his beliefs and teaching change through action research. The change of his teaching from the teacher-driven way before the treatment to more student-centered way after the treatment was shown by the use of S-T graphs and co-occurrence network diagrams of the observation data. It was interesting to notice that the teacher does not recognize the change in spite of the obvious change in his teaching style. Further discussions on the effects of action research for promoting active learning in high-school physics will be included in the presentation.

PAR-F.06: 2:30-3:30 p.m. Living Physics Portal: Designing Analytics to Map Faculty's Evolving Participation*

Contributed – Stephanie M. Williams, University of Maryland

Chandra Turpen, University of Maryland

Lyle Barbato, AAPT

The Living Physics Portal* (www.livingphysicsportal.org) is a website dedicated to cultivating a community in which physics faculty teaching interdisciplinary physics courses can discuss problems of practice and share curricular content. Our research team is interested in understanding faculty's use of the Portal. As part of this effort, we have been exploring what forms of participation can be tracked and meaningfully interpreted from users' actions. We have developed a model that categorizes particular actions on the Portal. The model of participation includes the following categories: Networking, Interpreting, Dialoguing, Collecting, Connecting, Creating, Remixing and Viewing. In this talk, we will showcase our model of online participation and apply this model to a single user's online activity.

*This work is supported by NSF #1624478 and #1624185.

PAR-F.06: 2:30-3:30 p.m. Longitudinal Impact of Flipped and Traditional Introductory Physics Courses

Contributed – Benjamin William Dreyfus, George Mason University, Fairfax, VA 22030

Rebecca M. Jones, An T. Hoang, George Mason University

The first two semesters of introductory calculus-based physics at George Mason University are taught in two parallel formats: a flipped section (taught in a SCALE-UP-style active learning classroom, replacing lecture and recitation) and a traditional lecture section. To assess the influence on these formats on student performance and retention, we analyzed a data set of over 1000 students who took the traditional and/or flipped introductory courses in 2013-15, and tracked them longitudinally through their subsequent physics and engineering courses. Initial results suggest that taking flipped Physics I is associated with higher grades in later courses, and taking flipped Physics II is associated with lower grades. However, the full picture is more complicated. A greater fraction of the students who take flipped Physics II go on to take advanced courses, which suggests that flipped Physics II is associated with higher overall retention in physics and related fields.

PAR-F.06: 2:30-3:30 p.m. Long-term Impact of Faculty Online Learning Community (FOLC) Participation

Contributed – Alexandra Lau, University of Colorado Boulder, Department of Physics, Boulder, CO 80309-0390

Melissa Dancy, University of Colorado Boulder

In this talk, we present results from our analysis of the long-term impacts of participating in the New Faculty Workshop-Faculty Online Learning Community (NFW-FOLC). The NFW-FOLC supports new physics and astronomy faculty as they implement research-based instructional strategies (RBISs) in their classrooms. A NFW-FOLC cohort meets regularly via videoconference over the course of one year. We have interviewed participants two years after the completion of their FOLC cohort to investigate the longitudinal impacts of FOLC participation on their current teaching practices. The main goals for NFW-FOLC participants are for them to develop as reflective practitioners and for them to successfully implement RBISs over the long term. We also hypothesize that participants may become change agents at their local institutions. We will speak to all three of these impacts in this presentation, discussing the potential of a FOLC experience to influence participants' teaching well after the FOLC stops meeting regularly.

Session PAR-F.07 PER: Student Content Understanding, Problem-Solving and Reasoning III

Tuesday, July 21, 2:30–3:30 p.m. Sponsor: AAPT

PAR-F.07: 2:30-3:30 p.m. Exploring Graduate Students' Understanding of Entropy

Contributed – Nate Crossette, University of Colorado Boulder, Boulder, CO 80309

Michael Vignal, Bethany Wilcox, University of Colorado Boulder

As a first step in a larger study of student difficulties in upper-division thermodynamics and statistical mechanics, we present the results of think-aloud interviews with graduate students on a set of entropy related questions. The four interview questions were developed to probe student understanding of entropy as a pressure towards equilibrium, as a quantity maximized in equilibrium, as a connection between microstates and macrostates, and as a macroscopic state-function. Exploring graduate students' understanding entropy and their ability to solve problems and reason with entropic arguments will provide insights into how physicists develop a mature understanding of entropy as a physical quantity. Specifically, we hope to see if new conceptual difficulties emerge as students progress to graduate school, and whether difficulties seen in undergraduate courses persist, evolve, or cease to present issues in the graduate setting.

PAR-F.07: 2:30-3:30 p.m. Identifying Student Conceptual Resources for Understanding Electric Circuits*

Contributed – Jonathan Corcoran, Seattle Pacific University, Seattle, WA 98119

Lauren C. Bauman, Quest University

Amy D. Robertson, Seattle Pacific University

Most research focusing on student ideas about electric circuits frames these ideas in terms of misconceptions, difficulties, and misunderstandings. Our project reports student resources for understanding electric circuits, ideas that we consider to be the "beginnings" of foundational understanding. In this talk, we will present four conceptual resources for understanding electric circuits based on our analysis of students' written responses to conceptual circuits questions. Our aim is to add to instructors' existing knowledge of students' ideas, supporting them in identifying and building on student resources for understanding electric circuits.

*This work is supported in part by NSF grants 1914603 and 1914572.

PAR-F.07: 2:30-3:30 p.m. Investigating and Improving Student Understanding of Quantum Mechanical Observables and their Corresponding Operators in Dirac Notation

Contributed – Chandralekha Singh, University of Pittsburgh, Pittsburgh, PA 15260

Emily Marshman, Community College of Allegheny County

Here we focus on an investigation that suggests that, even though Dirac notation is used extensively, many advanced undergraduate and Ph.D. students in physics have difficulty expressing the identity operator and other Hermitian operators corresponding to physical observables in Dirac notation. We first describe the difficulties students have with expressing the identity operator and other Hermitian operators corresponding to observables in Dirac notation. We then discuss how the difficulties found via written surveys and individual interviews were used as a guide in the development and validation of a Quantum Interactive Learning Tutorial (QuILT) to help students develop a good grasp of these concepts. We also discuss the effectiveness of the QuILT based on in-class evaluations. We thank the National Science Foundation for support.

PAR-F.07: 2:30-3:30 p.m. Investigating High School Students' Understanding of Wave Optics*

Contributed – Maja Planinic, University of Zagreb, Faculty of Science, Department of Physics, Zagreb, Croatia

Karolina Matejak Cvenic, Ana Susac, Katarina Jelicic, University of Zagreb

Lana Ivanjek, University of Vienna

Wave optics is a difficult teaching topic that was up to now usually investigated on university students. In Croatia, this topic is compulsory for a significant fraction of high school students, aged 18-19 years. In 2018. we started a four-year research project that includes investigation of high school students' difficulties with wave optics, construction of a new diagnostic instrument (Conceptual Test on Wave Optics), and development and testing of an experimental teaching sequence on wave optics. The final goal of the project is to investigate the effect of the new teaching approach, which includes several students' investigative experiments, on students' conceptual understanding of wave optics and on their scientific reasoning. Some preliminary results of the project will be presented, including findings from the 27 semi-structured interviews and from the process of the CTWO development. The most frequent students' conceptual difficulties regarding interference, diffraction and polarization of light will be discussed.

*This work has been fully supported by Croatian Science Foundation's funding of the project IP-2018-01-9085.

PAR-F.07: 2:30-3:30 p.m. Investigating the Impact of a Bottom-up Training on Newton's 2nd Law

Contributed – J. Caleb Speirs, University of New England, Biddeford, ME 04005

Thanh Lê, Western Washington University

Shawn W. Ell, University of Maine

Robyn Leuteritz, University of New England

Some physics questions prove difficult for students even after research-based instruction and demonstration of relevant conceptual knowledge. Recent studies have indicated that reflexive, bottom-up reasoning processes seemingly unrelated to conceptual understanding may be responsible for these difficulties. These studies also suggest that attending to these bottom-up processes during instruction may improve performance to a greater degree than attending solely to top-down, analytical reasoning. It is important to leverage these findings to produce meaningful improvements to instruction. Towards that end, we have investigated the impact of a training targeted at reflexive, bottom-up reasoning processes on questions related to balanced forces and compared results to a more standard, top-down approach to the same topic. This talk will relate the findings and suggest implications for future work.

PAR-F.07: 2:30-3:30 p.m. Secondary Student Perspectives of Quantum Physics

Contributed – Zac Patterson, The Ohio State University, Columbus, OH 43210

Lin Ding, The Ohio State University

Secondary physics curricula predominantly focus on physics content established prior to the 20th century (e.g., Newtonian mechanics, conservation of energy). Rarely are students exposed to modern physics topics (e.g., quantum mechanics, special relativity) in their formal education. Even so, students inevitably encounter terms such as “quantum” and “quantum physics” in their everyday lives. The aim of this study is to provide insight on secondary student perspectives of the terms “quantum” and “quantum physics”. While there is a body of research available that analyzes university physics majors' perspectives of quantum physics topics, little research has been done at the secondary level. Clinical interviews of students at a Midwestern high school are conducted to establish commonalities among perspective of quantum physics topics.

TUESDAY

PAR-F.07: 2:30-3:30 p.m. Student Conceptual Resources for Understanding Kinematics*

Contributed – Brynna H. Hansen, Seattle Pacific University, Seattle, WA 98119

Cheyenne M. Broadfoot, University of Washington

Amy D. Robertson, Seattle Pacific University

Physics education research on student understanding of kinematics has largely focused on misconceptions and difficulties. Our project reports student resources for understanding kinematics -- ideas that we consider to be the “beginnings” of sophisticated understandings. Our preliminary analysis highlighted four common resources that students are using to solve kinematics problems. In this talk, we will elaborate on the resources used most often by students and give examples from our preliminary research.

*This work is supported in part by NSF grant numbers 1914603 and 1914572.

PAR-F.07: 2:30-3:30 p.m. Tutorial to Connect Mathematics and Physics of the Heat Equation

Contributed – Sofie Van den Eynde, KU Leuven, Belgium

Mieke De Cock, Johan Deprez, KU Leuven

Martin Goedhart, University of Groningen

We developed a guided-inquiry tutorial to foster connections between mathematics and physics in the context of undergraduate thermodynamics, specifically the heat equation. Based on literature and empirical reasons, we formulated design principles that guided the development, including promoting graphical reasoning, stimulating thinking about physical meaning first, and paying explicit attention to the mathematical and physical aspects of concepts and ideas, and as such promote interdisciplinary connections. We determined the effectiveness of the design principles by testing the tutorial in teaching-learning interviews with three groups of three students each. In this session, we present the design principles and how they impacted the students' reasoning process. We aim to inform practitioners in the field who teach this subject, but furthermore anyone who wants to strengthen the connections between mathematics and physics in the topic they are teaching.

Session PAR-F.08 Introductory Courses II

Tuesday, July 21, 2:30–3:30 p.m.   Sponsor: AAPT

PAR-F.08: 2:30-3:30 p.m. An Ethnographic Approach to Understanding Informal Physics

Contributed – Bryan Stanley, Michigan State University, East Lansing, MI 48824

Dena Izadi, Kathleen Hinko, Michigan State University

We are continuing a nationwide effort to develop a systemic understanding of the landscape of informal physics using an organizational theory perspective. We have collected surveys and interviews with facilitators, but this information is only from the perspective of the faculty or physics student leaders and does not tell us about the social dynamics within each program. Thus, to complement these data, we need to observe informal physics events as they occur. In this talk, we will discuss our strategy for visits to program sites to observe social interactions between program participants as well as programmatic details in action. We report on an initial site visit to a physics open house outreach event, where we took field-notes and conducted formal and informal interviews with participating personnel members. Here, we discuss findings from applying an organizational framework to the site visit data and challenges we encountered in the data collection process.

PAR-F.08: 2:30-3:30 p.m. Building Models of Biological Systems in an IPLS Course

Contributed – Dawn Meredith, Physics Department, University of New Hampshire, Durham, NH 03824

Edward F. Redish, University of Maryland

There is agreement that being able to use, build, and/or evaluate models of biological systems is an important outcome for students in an IPLS course. We describe three biological systems (polyphonic overtone singing, sap moving up trees, and counter current exchanges) that are explicable (at least to first order) using introductory physics ideas. We share our “expert” models of these systems and consider how we could scaffold student development of these models.

PAR-F.08: 2:30-3:30 p.m. Physics Learning Goals versus AAPS Survey Results: Life Science Majors

Contributed – Andrew J. Mason, University of Central Arkansas, Conway, AR 72035-0001

The Attitudes and Approaches to Problem Solving (AAPS) Survey has been used to analyze students in introductory calculus-based physics, introductory math-based astronomy, upper division/graduate-level physics, as well as Turkish students in high school and introductory university physics. In this study, post-test survey results from introductory algebra-based physics course sections in 2019 and 2020 will be checked for statistical relationship with the following variables: 1) students' self-reported learning goals in introductory algebra-based physics courses; 2) students' choice of major (in particular, life science majors dominate the student population). From prior studies regarding these two variables, it is anticipated that students that express a mastery learning goal (as opposed to a performance learning goal or otherwise) may have more expert-like views than other students; discussion will focus on the accuracy of this statement and potential explanations for results.

PAR-F.08: 2:30-3:30 p.m. Presenting Physics Concepts via Head-Fake Learning

Contributed – Dan Young, University of North Carolina, Chapel Hill, NC 27514

Justin Hadad, University of North Carolina

Head-fake learning ("HFL") is a form of teaching material wherein the students do not realize the form or complexity of what they are learning. This occurs primarily when the mechanism through which the material is taught makes the students think they are learning something entirely different, i.e. how to succeed in Minute to Win It style mini-games instead of learning projectile motion. We discuss how we utilized HFL to present introductory physics and mathematical principles in a newly designed course at UNC entitled Game Show Theory, which uses game show structure and optimal play as a driving motivator. In addition, we will present examples of student work and testimonials regarding how they interacted with the course (and it's HFL methodology) and will discuss small-scale game show demonstrations which teach physics concepts with minimal cost.

PAR-F.08: 2:30-3:30 p.m. Relativity on Rotated Graph Paper: Diagrams for the Muon Experiment

Contributed – Roberto B. Salgado, Minnesota State University Moorhead, Moorhead, MN 56563

We analyze the Muon Experiment problem in Special Relativity using the author's Relativity on Rotated Graph Paper. After briefly introducing our method to visualize tickmarks on a spacetime diagram, we show how to calculate graphically using the counting of ticks and simple algebra. Using a simpler numerical example, we construct the diagram for the muon problem. We interpret the situation in the lab frame and in the muon frame. Finally, we use the more realistic values to obtain the standard numerical results. With more motivation for students, we feel that this approach can be used in an introductory algebra-based physics course.

Am.J.Phy. **84**, 344 (2016); https://doi.org/10.1119/1.4943251

PAR-F.08: 2:30-3:30 p.m. Smooth Transition to Concept-Focused Mechanics, Covering Concepts in Parallel

Contributed – Peter V. Schwartz, Cal Poly, San Luis Obispo, San Luis Obispo, CA 93401

Jennifer L Klay, Owen H. Staveland, Cal Poly, San Luis Obispo

Dean Stocker University of Cincinnati Blue Ash College

Parallel Pedagogy simultaneously introduces and develops the four mechanics concepts of Momentum, Energy, Dynamics, and Kinematics. We report on how our free, online comprehensive resources supported a first-time mechanics instructor to smoothly adopt this pedagogy. These resources include 100 public videos and a free online textbook/workbook, both of which are interactive through student access via PlayPosit and Perusall, respectively. The flipped format and online interactive resources are also ideally suited for conversion to virtual instruction with Zoom class meetings facilitating peer instruction and relationship-building. Student acceptance of this new model is built by transparently motivating practices with physics education literature and openly sharing the student adaptation experience. We'll show some positive learning outcomes. Consistent with this learning model, before our presentation please prepare (but come anyway if you can't).

1) See the video of our model for learning physics: https://api.playposit.com/go/share/225308/32670/0/0/Different-Way-to-Learn-Physics 2) Look over the most recent class: https://canvas.calpoly.edu/courses/22072

PAR-F.08: 2:30-3:30 p.m. Students' Visual Strategies During Physics Line-Graph Problems

Contributed – Stefan Kuechemann, TU Kaiserslautern, Germany

Sebastian Becker, Jochen Kuhn, TU Kaiserslautern

Graphs form an integral part during STEM education and the understanding of graphs is essential for the interpretation of data, critical thinking and reasoning in physics. Different previous works have shown that students struggle with specific difficulties, such as a confusion of slope and height, interpreting changes in height and changes in slope and the area underneath a curve. In this work we use eye tracking to study the question how the students' conceptual understanding of the slope and area concept is linked to the visual attention to different areas of a graph. Using machine learning and different gaze-based metrics, the eye-tracking data reveals characteristic visual strategies during solving of quantitative slope and area problems. The results allow the optimization of classifying correct and incorrect answers and the identification of underlying students' difficulties.

PAR-F.08: 2:30-3:30 p.m. Who Wins this Race?

Contributed – Carl E. Mungan, United States Naval Academy, Annapolis, MD 21401-3217

Two wheeled carts are identical except that one has its wheels taped so that it slides on them with kinetic friction. The other cart rolls frictionlessly. Both carts are placed at the bottom of identical side-by-side rails and propelled up them using identical spring launchers. The carts turn around and return to their starting location. Which gets back first? Or is it a tie? Video of an experimental demonstration will be shown, along with theory and computer simulations, to explain the interesting results.

Session PAR-F.09 Remote Delivery of Advanced Physics Labs Lessons and Victories

Tuesday, July 21, 2:30–3:30 p.m. Sponsor: AAPT

PAR-F.09: 2:30-3:30 p.m. A Home-Built Geiger-Müller Counter Based Modern Physics lab

Contributed – Paul W. Fontana, Seattle University, Seattle, WA 98122

In response to the COVID-19 epidemic, Seattle University moved all courses to remote instruction for spring quarter 2020. The Modern Physics Laboratory course PHYS 2060 was adapted by organizing it around the building, programming, and implementation of a home-built Geiger-Müller counter. Students had no prior LabVIEW experience and most had no electronics experience. They were provided with a National Instruments myDAQ board, an electronics breadboard, electronics components, and a schematic diagram [1] and given synchronous instruction via Zoom. They wrote LabVIEW VI's for lab bench tools and automated data acquisition. They designed and executed three nuclear physics experiments using their own software and hardware. Relative to the in-person format of the course, students executed a narrower range of experiments and did not study historic experimental literature, but gained data acquisition and electronics skills, experience in building and troubleshooting apparatus, and the satisfaction and self-confidence of making their projects from scratch.

[1] Circuit design from Michael Short, Mark Chilenski, and Matthew D'Asaro. 22.S902 Do-It-Yourself (DIY) Geiger Counters. January IAP 2015. Massachusetts Institute of Technology: MIT OpenCourseWare

PAR-F.09: 2:30-3:30 p.m. Advanced Laboratory at Home: From Single Photons to Chaos

Contributed – Margaret K. A. Koker, Lawrence University, Appleton, WI 54911

Douglas S. Martin, Lawrence University

Lawrence's Advanced Laboratory course trains students in experimental physics. Using research equipment, students engage deeply with real physics while learning scientific communication. Students worked on three self-selected projects using analog and digital electronics, ranging from single photon detectors to chaotic dynamics. Each student created an extension to one project, consisting of design and prototyping as well as collection and analysis of data. One student built an analog electronics neuron, firing upon exposure to a trumpet played at 392 Hz. Students shared project results with their scientific community via a scientific symposium (after students attended the APS Virtual April Meeting), an issue of Advanced Laboratory Letters at Lawrence (after PRL-based journal club discussions), and video demonstrations. Join us for a discussion of our approaches to evaluation and feedback, inclusive strategies, and course (and Zoom-related) fatigue. We will present what worked, what fell flat, and what surprised us along the way.

PAR-F.09: 2:30-3:30 p.m. Resources from ALPhA for Fall Advanced Lab Classes

Contributed – Ashley R. Carter, Amherst College, Amherst, MA 01002-5000

The Advanced Laboratory Physics Association (ALPhA) had meetings with ~30 advanced lab instructors from around the US and the world in May 2020. Many of those instructors talked about how hard it was to transition to online or remote lab classes during the Spring when the COVID-19 pandemic hit and about their worries for the Fall. These instructors asked ALPhA for two things: 1) increased communication to allow instructors to share ideas or to team up to solve problems, and 2) a curated list/database/website/document of resources that includes instructors' experiences. During June and July, ALPhA will focus on these two requests by facilitating member communication and posting instructor-curated resources. As secretary of ALPhA, I will report back about these resources and relay the most important take-aways. To get up-to-date information or to join the conversation, please visit the ALPhA website at advlab.org.

PAR-F.09: 2:30-3:30 p.m. Student Design of Advanced Lab Experiments at Home Using Available Resources

Contributed – Randall Tagg, University of Colorado, Denver, CO 80217-3364

Our Junior Lab requires four experiments per semester. In spring 2020 the final two experiments were done by students at home. They were asked to design their own experiments using available resources. Extra credit was given for an inventory of these resources, which varied quite widely amongst students. Details and computer code for one possible experiment was given to students: the use of mobile phone image sensors for cosmic ray detection. An alternative to the final experiment was to submit instead a white paper describing plans to develop an application of physics to the Covid19 pandemic; students were sent a primer on possible topics. Students were individually counseled on their projects by email and through Zoom meetings. The capacity of students to independently conceive of and execute experiments varied widely and revealed the need to better equip students with knowledge and skills to pose problems, deal with ambiguity, and work resourcefully with physical devices, materials, and supporting literature.

PAR-F.09: 2:30-3:30 p.m. Teaching an Advanced Acoustics Laboratory Course without a Laboratory

Contributed – Ronald E. Kumon, Kettering University, Flint, MI 48504

During the Spring 2020 quarter, the COVID-19 pandemic precluded access to our acoustics laboratory. In response, I redeveloped the experiments of our acoustics lab course in several ways. For some introductory activities, I employed videos to show basic concepts and methods in place of lab demonstrations and used applets to maintain some student interactivity. However, for most of the specialized experiments, I was able to draw upon past student work archived in electronic laboratory notebooks to extract photos, setup details, and experimental data sets. I then used that information to write activities that described the experimental methods, but required the current students to visualize, analyze, and interpret the data. To facilitate the course remotely, I used electronic laboratory notebooks to deliver and receive content. Preliminary indications are that the students are obtaining a similar understanding of the experimental methods and possibly better understanding of the data analysis than previous students.

Session PAR-F.10 Teaching Equity in Physics Tuesday, July 21, 2:30–3:30 p.m.

Sponsor: Committee on Diversity in Physics Co-Sponsor: Committee on Physics in Undergraduate Education

PAR-F.10: 2:30-3:30 p.m. Inclusive Physics & Astronomy Discussions at Western Washington University

Invited – Jess Mollerup, Western Washington University, Bellingham, WA 98225

Dimitri R. Dounas-Frazer, Western Washington University

In spring 2019, the Physics & Astronomy Department at Western Washington University began hosting weekly discussions about (in)equity. The main goals are to provide opportunities for students, staff, and faculty to develop a common vocabulary and shared knowledge about issues of (in)equity, and to explore how these issues manifest in our field. During these discussions, we learned about allegories for race and racism, models of oppression, characteristics of white supremacy culture, technical/social dualism, white fragility, white saviorism, invisible disabilities, microaggressions, physics metaphors for gender and sexuality, and the scope and limits of physics ways of knowing. The co-facilitators are a white male physics professor and a white nonbinary student, and the Physics & Astronomy Department is predominantly white and male. This talk will provide an overview of the background, purpose, guiding principles, content, and the experience of participants as conveyed through feedback surveys to be administered in the spring.

PAR-F.10: 2:30-3:30 p.m. Towards a Multimodal Semiotic Approach in Teaching Physics

Invited – Johan Tabora, University of Illinois-Chicago, Chicago, IL 60607

Maria Varelas, University of Illinois-Chicago

Teaching physics using a multimodal semiotic approach provides students with various opportunities to construct, represent, and communicate their developing understandings of physics concepts. Physics education research has shown that using multiple representations for problem-solving can enhance student learning. This talk extends the idea of multiple representations by arguing that engaging students in various semiotic modes such as speech, written text, gestures, images, and body positioning and movement not only enhances student physics understandings but also offers students different avenues of development and expression of their identities as physics learners that embrace their diverse sociocultural, racial, and ethnolinguistic backgrounds. Expanding our notion of what counts as valid physics representation provides a more equitable space for physics teaching and learning.

PAR-F.10: 2:30-3:30 p.m. What Parts of Ourselves Belong in a Physics Class?

Invited – Vashti A. Sawtelle, Michigan State University, East Lansing, MI 48824-2320

Abigail Daane, South Seattle College

Teachers of introductory physics spend a significant amount of time figuring out how to structure our classes to be inviting to many different students. One thing to consider is the culture of our classrooms and the physics community they represent. In this presentation, we offer a pathway to position activities in our classrooms as doing feminist science, thus inviting more students to see their ways of knowing and learning as part of our classrooms. We describe a lesson plan that supports students and instructors in reflecting on the problematic norms of physics culture. We aim to provide a foothold for identifying the stereotypical masculine and feminine elements of common classroom science lessons. We then describe a series of activities that support students in seeing different parts of themselves in the physics classroom and identifying how activities might privilege some identities and disempower others.

Session PAR-F.11 The Art and Science of Teaching

Tuesday, July 21, 2:30–3:30 p.m.

Sponsor: Committee on Physics in Undergraduate Education Co-Sponsor: Committee on Apparatus

PAR-F.11: 2:30-3:30 p.m. Fully Blended Online Course Using Modeling Approach to Problem Solving

Invited – David Pritchard, MIT, Cambridge, MA 02139-4307

Blended learning with flipped classrooms – where online pre-class instruction precedes highly interactive classes - outperforms traditional pedagogy. It also challenges the organizational and cognitive load capabilities of instructors. Placing the required resources: videos, interleaved questions, in-class activities (short instructor presentations, group problems, and other activities), homework, and quizzes in a single online platform allows creating and organizing assignments to fit various weekly class schedules. I will describe an Introductory calculus-based Mechanics course using the Modeling Approach to Problem Solving pedagogy (1&2), emphasizing the online in-class activities. We use the edX platform to handle and deploy the resources, supplemented by an organizational software package that displays sufficient metadata to create and assess a balanced learning experience, and to improve outcomes year to year based on the collected metadata. We are grateful to MIT for help generating resources and making the organizational software package. Please consider adapting this course for your students.

(1) Pawl, A., Barrantes, A., Pritchard, D. E., Sabella, M., Henderson, C., & Singh, C. (2009). Modeling Applied to Problem Solving. In M. Sabella, C. Henderson, & C. Singh (Eds.), Physics Education Research Conference (pp. 51–54). https://doi.org/10.1063/1.3266752 (2) Rayyan, S., Pawl, A., Barrantes, A., Teodorescu, R., Pritchard, D. E., Singh, C., … Rebello, S. (2010). Improved Student Performance In Electricity And Magnetism Following Prior MAPS Instruction In Mechanics. In Physics Education Research Conference 2010 (pp. 273–276). Oregon, Portland. https://doi.org/10.1063/1.3515221

PAR-F.11: 2:30-3:30 p.m. The Basic Science of Teaching to Improve Practice and Outcomes*

Invited – Gay B. Stewart, WVU, Morgantown, WV 26501

John C. Stewart, WVU

Physics education is full of instances of those who have abandoned reforms because they did not seem to work. Surprise: A talk or even a workshop is not enough to provide instructors deep conceptual understanding of how students learn physics! Courses are complicated systems that must be well designed to provide the best learning experience possible and significant learning can take place in many different types of courses. The science of teaching begins with understanding what student behaviors lead to learning. Many of the elements behind effective reformed courses have the same student behavior goal. Focusing on these goals may help faculty implement effective reformed instruction. I will present some of these important behaviors. Getting students to engage in them leads to improved learning. The art comes in with the question: Can we get the students to like it?

*This work draws on results of many NSF-funded projects of which John or Gay Stewart has been PI, especially ECR-1561517 and HRD-1834569 and going back to CCD-9455732.

Session PAR-G.01 Computer Modeling and Computation in Labs **Wednesday, July 22, 10:00–11:00 a.m.**
Sponsor: Committee on Educational Technologies Co-Sponsor: Committee on Laboratories

PAR-G.01: 10:00-11:00 a.m. Adding Computation to the Introductory Physics Lab

Invited – Ashley Carter, Amherst College, Amherst, MA 01002-5000

There have been many recent calls to overhaul the introductory lab course. This is because it doesn't meet a commonly stated goal of reinforcing lecture content (Holmes et al., *Physics Today*, 2018), nor is it focused on teaching experimental skills like designing experiments and analyzing data (Kozminski et al., AAPT, 2014). In addition, it doesn't teach computational modeling—where students use computational tools to conceive, construct, or test models—even though the laboratory is where this modeling would naturally occur (Behringer et al., AAPT, 2017). One method to overhaul the course that is gaining traction is to have students engage in open-ended projects. I will discuss implementation of this method and how it can be used to teach computational modeling to introductory students without any computational skills. This discussion will include computational practicums, emphasizing modeling in the lab notebook, requiring students to vary two variables in their models, and building in iteration.

PAR-G.01: 10:00-11:00 a.m. Arduinos Used to Integrate Programming Skills into an Advanced Lab

Poster – David Sidebottom, Creighton University, Omaha, NE 68178

Guided by recent AAPT guidelines, reorganization of the lab sequence at Creighton University resulted in a new, intermediate-level course designed to teach the six skills that practicing scientists rely on: constructing knowledge, modeling, designing experiments, developing technical and practical lab skills, analyzing and visualizing data, and communicating physics. As a way of introducing fundamental programming skills, students are tasked to integrate a microprocessor (Arduino Uno) with simple sensors to create basic data acquisition and control systems that can automate measurements. Here we highlight two examples. The first is a simple temperature controller used to maintain the temperature of an aluminum block. The second is a large angle pendulum whose amplitude and half period are measured using a rotary encoder. In both instances, students are challenged to design the program and troubleshoot its final application in the real world.

PAR-G.01: 10:00-11:00 a.m. Capture, Code, Compare: Integrating Computational Modeling with Video Analysis

Poster – W. Brian Lane, Jacksonville University, Jacksonville, FL 32211

It's clear that computational modeling has significantly impacted physics education. However, there remains a gap in student sensemaking between the results they see in a computational model and their observation of the physical world. To help my students see that their computer models actually describe reality and learn how to quantitatively discuss how well model and reality match, I've developed the Capture, Code, Compare (CCC) activity structure. In CCC, students capture the motion of a physical system and study that motion through video analysis, develop a code that reproduces the motion in a computer animation, and compare the results of the video analysis and animation. This poster will present sample CCC activities and discuss possible means of assessment.

PAR-G.01: 10:00-11:00 a.m. Computational Modeling of Seiche in an Circular Above-Ground Pool

Poster – Hugh A. Gallagher, SUNY Oneonta, Oneonta, NY 13820

Benjamin Weir, SUNY Oneonta

Melissa Marry, University of New Hampshire

A surface seiche is a regular oscillation of the surface of an enclosed body of water such as a lake or bay. This project examines the formation of a seiche in a small circular above-ground pool. Analyzing observations from an ultrasonic range sensor, we determine the initial amplitude, period and decay constant of the seiche to be 6.2 cm, 1.975 s and 340 s, respectively. Since the decay time constant is much larger than the period, frictional effects should have a relatively small impact on the period of the seiche. We use a finite difference scheme to solve the wave equation in cylindrical coordinates for the surface height. We find that the theoretical period agrees with the observations if a wave speed consistent with the pool dimensions is used instead of the wave speed provided by the shallow wave approximation.

PAR-G.01: 10:00-11:00 a.m. Computational Simulations of Introductory Lab Experiments in Physics I

Poster – Deva A. O'Neil, Bridgewater College, Bridgewater, VA 22812

Introductory calculus-based physics is taught at Bridgewater College with both laboratory and computational components. Simple programming in Glowscript (a vpython environment) is introduced to students in recitation section. In two of the lab experiments (cart sliding with constant velocity, collision between two carts), students use the experimental data to determine the parameters for a numerical simulation of the system. The computational activities are designed to provide practice with momentum conservation and with updating the position of an object based on its previous position and velocity. Integrating them with lab activities is intended to promote understanding of the physical parameters. If coded correctly, the numerical output will resemble the experimental data, providing plausibility checks on the code. A more advanced laboratory activity done in Physics I, the ballistic pendulum, has also been simulated numerically by a student as an Honors Upgrade. The simulation applies the principle of momentum conservation to reproduce the motion of a pendulum after a collision with a projectile.

PAR-G.01: 10:00-11:00 a.m. Modeling linear and Non-linear Drag in Horizontal Oscillatory Motion

Poster – Kyle Slinker, North Carolina School of Science and Mathematics, Durham, NC 7705

Eleanor Murray, North Carolina School of Science and Mathematics

Exponentially damped oscillatory motion is often encountered early in a physics student's education. The closed form solution in the case of linear-in-velocity drag makes this an attractive first model, but realistic systems typically include constant- and/or quadratic-in-velocity drag. The equations of motion for non-linear drag can be solved numerically so that data can be fit using more accurate models. A data set is presented and analyzed which students can use to explore topics such as differing models of friction, numerical modeling techniques, and evaluating and quantifying the agreement between a model and data. Code and data are provided for physics instructors' use.

PAR-G.01: 10:00-11:00 a.m. Modern Computer Applications in the Advanced Laboratory

Invited – Daniel Borrero, Willamette University, Salem, OR 97301-3930

While computers have long played an important part in physics laboratory instruction, the scope of their use is often limited to relatively simple data processing tasks like fitting experimental data to well-established analytical models. While these applications are obviously important, they are not representative of the full range of ways that computers are used in modern physics research laboratories. In this talk, I will discuss how the physics department at Willamette University has created engaging laboratory experiences that tightly integrate experiment, theory, and computational modeling and incorporate modern computational tasks like data visualization, simulation of experimental systems, and computer-aided design and fabrication of experimental apparatus. These activities have reduced the time that faculty spend training undergraduates to work in their labs allowing students to make more significant research contributions, while also helping them acquire crucial computation skills that they will need as they join the 21st century workforce.

PAR-G.01: 10:00-11:00 a.m. Radiological Physics Simulation of Radiographic Image Acquisition

Poster – Peter J. Riley, Deakin University, Geelong, VIC 3216 Australia

Radiology practitioners are examined on the underlying radioloical physics principles of Photoelectric Absorption and Compton Scatter. Students must understand how these interactions in the patient vary as the x-ray tube acquisition parameters are adjusted. This variation changes the relative tissue contrasts in the radiograph and the detrimental radiation dose to the patient. An interactive Mathematica (1) simulation has been developed which simultaneously shows relative interaction probabilities, patient dose & penetration, and an anthropomorphic chest image. By adjusting the parameters the student can determine an optimal acquisition which minimises patient dose whilst generating sufficient contrast for lesion detection on the radiograph. The simulation instructions lead the student through a series of acquisitions which enable MCQ & SAQ assessments, which have demonstrated enhanced and accelerated comprehension. 1. Mathematica, Wolfram Research Inc., Champain, IL (1989-2020).

PAR-G.01: 10:00-11:00 a.m. Simulating a Pandemic

Poster – Herbert Jaeger, Miami University, Oxford, OH 45056

Ever since the emergence of the novel corona virus (COVID-19) earlier this year, we have been bombarded with numbers representing observations, estimates, and results of modeling the outbreak of the virus. Models in particular are interesting as they allow to play out a number of scenarios and so help to determine the effectivity of actions with respect to slowing down the infection. In this contribution we show how such a model can be approached so it is suitable for use in an undergraduate computational physics class or an independent study project. The results of this simple simulation show how an outbreak can be affected by measures such as social distancing.

PAR-G.01: 10:00-11:00 a.m. Understanding COVID-19 by Modeling It

Poster – Peter Hugo Nelson, Guilford College, Greensboro, NC 27410

Simple epidemiological models are introduced using finite difference methods in Excel. The SIR model explains the initial exponential growth of COVID-19, the effects of social distancing in the US during early April 2020 and successfully predicts the continued spread of the virus during late April and May 2020. The SIR model is the origin of the basic reproduction number R0 and herd immunity. It also predicts what will happen if social distancing is lifted prematurely. A wide range of student research projects are possible for modeling and making predictions based on real data for US states and other countries. See http://circle4.com/biophysics for free sample chapters and videos.

Session PAR-G.02 Exploring Virtual and Augmented Reality in Physics Education

Wednesday, July 22, 10:00–11:00 a.m.

Sponsor: Committee on Educational Technologies Co-Sponsor: Committee on Physics in Undergraduate Education

Virtual and Augmented Reality (collectively eXtended Reality or XR) allow users to observe and manipulate content in 3D, use natural motion controls to explore phenomena, and make tangible otherwise abstract or invisible quantities, among other affordances. By leveraging these capabilities, instructors are developing myriad novel methods of teaching physical concepts. This session will be a space for instructors to share their ideas and applications in a two-part session. The session will open with talks outlining the technologies and current and potential applications in the physics classroom. As understanding XR applications is challenging without the chance to experience them, the session will transition to tabled demonstrations, where attendees will be able to experience for themselves all of the XR content discussed in the talks.

PAR-G.02: 10:00-11:00 a.m. Designing and Assessing the Efficacy of VR Educational Games

Invited – Mina C. Johnson-Glenberg, ASU and Embodied Games, Tempe, AZ 85283

Virtual Reality (VR) leverages two “profound affordances”: 1) presence and 2) the agency associated with manipulating content in 3D to explore multidimensional and spatial phenomena. At the Embodied Games lab at Arizona State University, we create VR content that uses presence to get the students’ undivided attention, and then we ensure that all content is interactive and embodied (via gesture and motion capture). Dr. Johnson-Glenberg will present two games and one AR application (designed with Vierya software). The first game is available at the Oculus Store for free and instructs in natural selection (called “Catch a Mimic”). She will present data on best uses of VR and learning gain differences between VR and 2D PC platforms. The second is a new game on Tuned Mass Dampers (think the Taipei 101 building). She will seek audience feedback on how to optimize the educational game for a physics and engineering lesson.

PAR-G.02: 10:00-11:00 a.m. Modeling Novel Physics Using Virtual Reality in Introductory Physics Laboratories

Invited – Jared Canright, University of Washington, Seattle, WA 98115-6253

Suzanne Brahmia University of Washington

Peter Shaffer University of Washington

Generating mathematical models of phenomena is central to the practice of physics. Since there is typically no physics in the introductory sequence for which a model doesn't already exist, most laboratory experiences are structured as hypothesis-testing experiments in which students are given a model to verify. As a part of the introductory lab transformation project at the University of Washington (UW) - informed by the Investigative Science Learning Environment learning system - the Physics Education Group has created an authentic model-generating learning opportunity. Using a virtual reality environment, students explore physical phenomena that do not exist in the real world (or Wikipedia). Students generate mathematical models describing these phenomena from scratch, applying reasoning skills similar to those used by research scientists. This talk will describe the development of the "artificial" phenomena, their implementation in UW introductory electromagnetism labs, and the labs' impact on students' learning and development of scientific reasoning.

PAR-G.02: 10:00-11:00 a.m. Teaching 3D Physics Concepts with Augmented Reality

Contributed – Nick Giordano, Siena College, Albany, NY 12211

Michele McColgan, Graziano Vernizzi, Siena College

Students find difficulty visualizing 3D concepts in our physics courses. In our introductory calculus-based physics and upper-level electricity and magnetism courses, students struggle to visualize electric and magnetic fields, electric flux, Gauss’s law, electromagnetic induction, three-dimensional integration, and the divergence theorem, to name a few of the E&M topics that are well suited for visualization using augmented reality. For example, when teaching Gauss’s law, the mathematical formalism tends to hide the geometrical meaning of Gauss’s law, more than explain it. Therefore, an AR hands-on visual representation can greatly help in rendering the concepts of flux through a surface or charge density in a given volume, so as to help students understand the physics behind it. In this poster presentation, we will demonstrate the AR applications and activities that we’ve developed and plan to use in our courses.

WEDNESDAY

Session PAR-G.03 Impact of Evidence-based Active Engagement Pedagogies on Student Learning

Wednesday, July 22, 10:00–11:00 a.m.

Sponsor: Committee on Physics in Undergraduate Education   Co-Sponsor: Committee on Physics in High Schools

PAR-G.03: 10:00-11:00 a.m. Active Engagement and Real Applications: Ohio State's Honors Robotics Project

Invited – Kathleen Harper, The Ohio State University, Columbus, OH 43210

The Fundamentals of Engineering for Honors program at The Ohio State University actively engages first-year students contemplating engineering in realistic engineering experiences. This helps solidify their understanding of what engineering is, the kinds of activities engineers engage in, and the elements of engineering design. The most popular second-semester course includes a substantial robotics project which includes planning, budgeting, documentation, teamwork, and of course the technical aspects of designing, programming, constructing, and testing a robot. This course is now in its 25th year. Instructors have based course refinements on results in the science education literature and also assessed the impact of course modifications on the student and teaching assistant experiences. This presentation will give an overview of the project and share multiple examples of the varied ways students are made to be active in their learning process.

PAR-G.03: 10:00-11:00 a.m. Kinematic Robots Foster Student Inquiry by Optimizing Student Feedback

Invited – Matthew Greenwolfe, Cary Academy, Cary, NC 27513

In this talk, I describe the design of a robotic kinematic apparatus and a curriculum designed to make use of its unique features to shape the inquiry process. Students program a robot by drawing kinematic graphs on a computer, and the robot precisely and reliably produces the motion, providing immediate visual feedback. Preliminary results support the hypothesis that a physics apparatus precise and reliable enough to serve as a control of error minimizes the need for teacher intervention and improves student absorption in inquiry as well as learning outcomes. The importance of optimal feedback inertia emerged from the study. The turn-around time of several minutes to analyze a mistake and test a new idea encourages students to learn from their mistakes and really think things through.

PAR-G.03: 10:00-11:00 a.m. Race to Improve Student Understanding of Uncertainty: Using LEGO Race Cars in the Physics Lab

Invited – Maria Parappilly, Flinders University College of Science and Engineering, Adelaide, Australia

A novel method is proposed for how LEGO race cars can help students increase their understanding of uncertainty and motivate them in physics labs. The intervention was developed for students in an introductory physics topic with a high early drop-out rate. This intervention was extended into the intro level physics topic the next year, for comparison and evaluation. A qualitative survey of the students was taken to gain insight into their perception of the incorporation of LEGO into physics labs. In this talk, I will discuss the results of the study and how variations in the delivery yielded better learning outcomes. We subsequently adapted the delivery of the LEGO labs for a large Engineering Mechanics cohort. For Engineering, the findings show that LEGO physics was instrumental in teaching students ideas of measurement and uncertainty, improving their lab reporting skills, and was a key factor in reducing the early attrition rate.

PAR-G.03: 10:00-11:00 a.m. Toward a Neurobiological Basis for Understanding Learning in Physics Courses

Invited – Jessica E. Bartley, Florida International University, Miami, FL 33199

Katherine L. Bottenhorn, Matthew T. Sutherland, Florida International University

Eric Brewe, Drexel University

Angelia R. Laird, Florida International University

There is a rich literature investigating the impact of physics pedagogy on student learning. Significantly less, however, is understood about the fundamental neural mechanisms that accompany learning across physics classroom environments. In this study we provide the first neurobiological evidence demonstrating physics instructional approach yields large-scale reorganization in student's brain networks. We used functional magnetic resonance imaging (fMRI) to measure physics-related brain activity in University students and probed for differences resulting from a semester of Lecture or Modeling physics classroom instruction. Students underwent pre- and identical post-instruction fMRI sessions where we assessed their brain activity during physics reasoning and identified regions more engaged post- relative to pre-instruction. We describe key project findings, including consistent brain activity associated with physics-related cognition, evidence that different knowledge organizations are paralleled by differential engagement of physics-related brain networks, and the characterization of neurobiological changes associated with classroom learning across contrasting pedagogies.

Session PAR-G.04 Introductory Labs/Apparatus

Wednesday, July 22, 10:00–11:00 a.m.   Sponsor: AAPT

PAR-G.04: 10:00-11:00 a.m. An Instrument to Measure the Little-g in Teaching Labs

Contributed – Jingbo Ye, Southern Methodist University, Dallas, TX 75205-0100

I will present the instrument that I have developed to measure the gravitational acceleration g in teaching labs. This instrument employs two independent methods, one includes the g-ball to obtain time of a free-fall, the other is a simple pendulum, to measure the same physics quantity with precisions within a few percent. This provides students with information to discuss about systematic and random errors in the measurements. I will share the lab manual (pre-lab, discussion questions, a skeleton for lab-report), data acquisition guide (a spreadsheet), and the information about how to DIY this instrument with those who would be interested in trying it in their labs.

PAR-G.04: 10:00-11:00 a.m. Incorporating Python-based Digital Notebooks into Introductory Physics Labs

Contributed – Diego Valente, University of Connecticut

James Jaconetta, Zac Transport, University of Connecticut

As part of our large-scale transition to studio-based instruction in our introductory physics courses, we were faced with the challenge of redesigning our lab experiments to significantly shorten lab sessions. To better streamline our lab activities, we have implemented Python-based digital notebooks. In addition to shortening the amount of time students spend writing their reports, these notebooks allow for a flexible implementation of data analysis that can be tuned to the level of the course, while also allowing for the utilization of open-ended questions to assess student understanding and the incorporation of coding in an introductory physics lab setting. This work presents details of our redesign, including our initial steps implementing labs using Jupyter notebooks before we decided on the utilization of the Google Colab cloud-based platform. We discuss advantages and disadvantages of both platforms, as well as measures we have implemented to mitigate plagiarism of work submitted by students.

PAR-G.04: 10:00-11:00 a.m. Integrating Laboratory and Computation: An Adjustable Physical Pendulum

Contributed – Ernest R. Behringer, Eastern Michigan University, Ypsilanti, MI 48197

Steven Temple, San Rafael High School

Mechanics provides many opportunities for integrating computation into physics curricula. We have developed different versions of an adjustable physical pendulum that can help students learn and apply rotational motion concepts while achieving many of the learning outcomes described in the AAPT recommendations for the laboratory curriculum and for computational physics. Because these pendula undergo large amplitude oscillations, they are difficult to investigate analytically. Instead, students can computationally model the experimental data they obtain with these pendula using spreadsheets or structured language programs to better understand the underlying mechanics, and determine whether different dissipation mechanisms are active while the pendulum 'rings down'. We describe the construction and use of these pendula and the results that can be obtained.

PAR-G.04: 10:00-11:00 a.m. Measuring the Speed of Light: Teaching Statistics Through Experiments

Contributed – Rebekka Frøystad, Niels Bohr Institute, Copenhagen, 2100 Denmark

Ian Gardner, Bearden Niels Bohr Institute

We have developed a lab for measuring the speed of light (c) aimed at high school students. Light is emitted from an LED lamp to a beamsplitter, where part of the light is reflected to a monitor. The rest hits a reflector and upon returning to the beamsplitter is reflected again and measured by another monitor. By increasing the distance between the beamsplitter and the reflector, the time difference between the signals can be measured and c extrapolated from performing a linear regression on the measurements. The students see first hand the importance of making consistent measurements and gain experience in handling electronic equipment. Usually, individual groups of high school students measure values of c deviating by about 10-30% from the accepted value. However, when we analyze the data sets of all groups in a class, we typically find results with about 3%. This sparks productive discussions on statistics.

PAR-G.04: 10:00-11:00 a.m. Student-Centered Approach to Online Radiation Experiments During a Pandemic

Contributed – Yugjeet Grewal, California State University, Fresno, CA 93630-1999

John Walkup, California State University, Fresno

First-year students at California State University, Fresno learn to perform scientific research through a Building Opportunities with Networks of Discovery (BOND) course sequence. Students perform their own research as a culminating project. Although COVID-19 eliminated on-campus student involvement, one group of freshmen was undeterred. Spurred by a presentation on the dangers of radium, they decided to complete their research nevertheless. Using a Geiger-Muller tube and sound-capturing software, they measured to reasonable precision the half-layer of steel in absorbing high-energy gamma rays emanating from a Revigator, an early quack medical device. The study describes how they conducted radiation exposure experiments through Zoom, with the instructor acting in the reversed role of "Lab Rat," and how their procedure can drive similar online radiation experiments without compromising student safety. Finally, it describes how such a project offers lessons in medical history, especially disasters that unfolded when greed and ignorance supplanted science.

PAR-G.04: 10:00-11:00 a.m. Supporting Student Understanding of Linear Fitting with Non-identical Uncertainties

Contributed – Saima Farooq, Univeristy of Maine, Orono, ME 04469-5709

Mary Jane Yeckley, MacKenzie R. Stetzer, Univeristy of Maine

Students in introductory physics laboratories often do not recognize the importance of estimating uncertainties – sometimes dismissing it as busy work. In addition, they often struggle with accounting for uncertainties in their measurements when reporting their findings. Here, we describe the implementation of a new laboratory activity in the calculus-based introductory physics sequence, which was informed by an emerging body of research on laboratory instruction. This laboratory activity focuses on the impact of measurement uncertainties on the construction of a linear best-fit model, particularly when the data points have non-identical uncertainties. In this talk, we will also share preliminary results from pre- and post-laboratory assessments.

PAR-G.04: 10:00-11:00 a.m. They're Smarter than Us: Algebra-based Learning Assistants in Calculus-based Labs

Contributed – Samuel Engblom, University of Illinois Urbana-Champaign, Urbana, IL 61801

Mats A. Selen, University of Illinois Urbana-Champaign

Introductory physics labs at the University of Illinois Urbana-Champaign make use of Undergraduate Learning Assistants (LAs) to assist with the implementation of reformed lab activities. As the reformed lab program has been scaled up to include a greater selection of introductory courses, the high initial demand for LAs in calculus-based lab sections has led to expert LAs (ELAs) from the algebra-based introductory physics courses being recruited to teach in lab sections beyond their course experience. In this presentation, the attitudes and traits of the ELAs that choose to make the jump to the calculus-based introductory physics labs will be discussed, along with the provisions made within the lab course to aid with the transition.

PAR-G.04: 10:00-11:00 a.m. Transformation of introductory mechanics lab at Fort Lewis College

Contributed – Alexandra A. Werth, University of Colorado Boulder

Laboratory courses offer opportunities for engagement in authentic practices of science; however, there have been recent concerns raised on the effectiveness of labs at reaching this goal. Here, we present on our initial research on transforming an introductory mechanics lab at Fort Lewis College (FLC) in Durango, CO. FLC is one of six designated Native American-serving, non-tribal colleges by the U.S. Department of Education and is one of the most diverse colleges in the nation—FLC has approximately 4,000 undergraduate students, 25% of which are American Indian or Alaska Native identifying. We began our work by actively seeking out input on goals and content for the labs both from students and faculty members. We report on the consensus learning goals determined from faculty interviews, the formation of a Student Advisory Council, the development of the structure and guiding principles of the lab, and our initial research findings.

PAR-G.04: 10:00-11:00 a.m. Treatment of Statistics and Error in Introductory Physics Lab Manuals

Contributed – Jimmy Gonzalez, University of California, Merced CA 95343

John R. Walkup, California State University, Fresno

Many students experience their first practical application of statistics and error analysis conducting activities in their introductory physics labs. During this time, they learn definitions, concepts, and skills they will use for the rest of their academic and postgraduate career. The presenters will discuss their analysis of the use of statistical methods used in labs by comparing lab manuals aimed at science and engineering students collected from two-year community colleges and four-year universities. Approaches to introducing statistical concepts and procedures are examined for consistency, with particular reference to national and international guidelines such as the NIST and ISO. Their analysis reveals severe inconsistencies in the treatment of statistics and error among the samples. Most notably, wide disparities surfaced in terminology and relationships, along with a dearth of topics that should have warranted a more concerted treatment. Results point to inadequate development of statistical reasoning skills among future scientists and engineers.

PAR-G.04: 10:00-11:00 a.m. Using 3D Printed Atomic Force Microscope Models to Facilitate Instruction

Contributed – Merrell A. Johnson, Purdue University, Fort Wayne, IN 46805

Three low cost, raspberry pi controlled atomic force microscope models will be presented. Two of the systems are more compact, which utilize inexpensive servo motors and either laser cut or 3D printed components to build the two dimensional scanners. The third larger system uses 3D printed parts, a series of stepper motors and belt drives to create a scalable scanner. A series of investigations that were created as precursors to operating the instruments will be presented. The goal of these experiments is to help students understand concepts pertaining to the resonance of cantilevers and how those ideas are employed in measuring forces. A presentation on how the knowledge relevant to measuring forces with cantilevers and the two dimensional stages are used to map a metallic surface with a magnetic probe. A discussion on how these systems were employed for instruction in the classroom will also be exhibited.

PAR-G.04: 10:00-11:00 a.m. Using PHET Simulations to Improve Scientific Abilities in Students

Contributed – Rex N. Taibu, Queensborough Community College of The City University of New York

Lloyd Mataka, Lewis–Clark State College

Shekoyan Vazgen, Queensborough Community College of The City University of New York

Science educators usually face a lot of challenges in designing and implementing inquiry-based activities. Common challenges include limited apparatus and time constraints. In this study, students were engaged in scientific inquiry using Physics Education Technology (PHET) simulations via semester-long group projects. The instructor and students used the Scientific Abilities Assessment Rubrics (SAAR) to evaluate project presentations and papers (formative assessment). The overall research project was evaluated using lab assessment scale (pre and post) as well as the post reflection survey. The Science Process Skills Inventory (SPSI) was used to analyze students' responses to the reflection survey. Quantitative analysis of the lab self-assessment scale showed a larger effect size for both introductory and general physics students. Qualitative analysis of the reflection surveys supported this apparent huge gain in lab skills and revealed students' experiences of the PHET simulations.

PAR-G.04: 10:00-11:00 a.m. Measuring the speed of sound with 3 technologies

Contributed – Alan Bates, Bedford School De Parys, Avenue Bedford, Bedfordshire MK402TU United Kingdom

The author applies 3 different technologies to measure the speed of sound in air: a. Pasco motion sensor with Capstone software; b. Arduino board with ultrasonic distance sensor; c. Phyphox, sonar-timing, smart phone app. Each technique offers a particular learning challenge and experience with a common outcome. With the different technologies, there is greater access to the experiment be it at home or in the school lab. Each of the experiments naturally give rise to open-ended investigations related to the speed of sound.

Session PAR-G.05 Introductory Physics for the Life Sciences (IPLS)

Wednesday, July 22, 10:00–11:00 a.m. **Sponsor: Committee on Physics in Undergraduate Education**

PAR-G.05: 10:00-11:00 a.m. A Calculus-based Studio IPLS Course Sequence at UConn

Poster – Xian Wu, University of Connecticut

At University of Connecticut, we have been designing a studio physics course sequence for life science students. Several non-traditional, bio-relevant physics topics are adapted to meet the needs of the students. In 2020 summer semester, a mock-up studio physics course is taught to test out the content and the structure of the course. We assess student conceptual learning, problem-solving ability, and attitude toward physics via exams and surveys built locally and the research-based assessments. We will address the limitations of the popular research-based assessments on probing the learning outcomes of the studio physics course for the life sciences.

PAR-G.05: 10:00-11:00 a.m. A New IPLSCourse: Five Years Later*

Invited – Alice D. Churukian, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599

Duane L. Deardorff, Laurie E. McNeil, Colin S. Wallace, Daniel E. Young, University of North Carolina at Chapel Hill

At the University of North Carolina at Chapel Hill, we completely transformed our two-course sequence of introductory physics for life science majors (IPLS) into the integrated lecture/studio format using biological phenomena to motivate the physics. Across both courses, we have created a suite of 54 active-engagement studios, interactive lectures, and assessment questions, all of which have been developed using the findings and best-practices from PER. This suite includes materials for many topics that are important for life science majors, but not part of the traditional introductory physics curriculum, including non-linear stress/strain, diffusion, chemical energy, and life at low Reynolds numbers. Now five years after the first complete implementation, the two-course sequence is running smoothly. In this talk, I will provide an overview of our journey from germination to realization.

*This work has been supported in part by NSF DUE-1323008 and AAU Undergraduate STEM Education Initiative

PAR-G.05: 10:00-11:00 a.m. Click and Drag Digital Worksheets for Online Biomechanics Activities

Poster – Nancy Beverly, Mercy College, Dobbs Ferry, NY 10522

Click and drag digital worksheets were created on which students can click and drag vectors, lines, text boxes, and symbols to create motion, force, and torque diagrams, as well as analyze graphs for biomechanics scenarios. These were made for use by student groups during an online synchronous introductory physics for life science class, but could be used in a myriad of other ways.

PAR-G.05: 10:00-11:00 a.m. Incorporating Computation into a Physics Course for Life Science Students

Poster – Kirtimaan Mohan, Michigan State University, East Lansing, MI 48824

Kathleen Hinko,Vashti Sawtelle, Michigan State University

Introductory Physics for the Life Sciences (IPLS) courses are gaining momentum in the physics education community, with the creation of multiple curricula for a variety of implementation strategies. At Michigan State University, we have designed an integrated lab-lecture (studio style) introductory physics course that meets the needs of life science students. Our design of this course focuses on incorporating computational simulations that model complex biological phenomenon and complement empirical lab investigations. We will present on updates to a unit on diffusion in which we incorporated a series of computational tasks designed to build up students' understanding of collisions and random motion. In this presentation we will describe changes that we have made to the unit and how those changes supported student understanding and engagement.

PAR-G.05: 10:00-11:00 a.m. Introductory Physics at CU Boulder

Invited – Daniel R. Bolton, University of Colorado, Boulder, Boulder, CO 80309

How can we achieve our teaching and learning goals in an introductory physics course for non-majors? At CU Boulder we are employing an array of strategies including group work, reformed labs, and two-stage exams. We will also discuss how a department can encourage good teaching by using research-based assessments and teaching circles.

PAR-G.05: 10:00-11:00 a.m. Modeling the Variable Moment of Inertia of Limbs During Locomotion

*Poster – Melissa A. Vigil, Marquette University, Milwaukee, WI 53201-1881*Analysis of gross motor motion is of particular importance to future physical therapists in our IPLS courses. Using the work of Thollesson & Norberg (J.Exp.Bio, 1991) as a starting point, students use LEGO bricks and Tinker Toys to model the changes in moment of inertia of arms and wings both from the definition of moment of inertia as the sum of mr^2 terms and from the movement of the model as a physical pendulum.

PAR-G.05: 10:00-11:00 a.m. Physics Learning Goals Versus AAPS Survey Results: Life Science Majors

Poster – Andrew J. Mason, University of Central Arkansas, Conway, AR 72035-0001

The Attitudes and Approaches to Problem Solving (AAPS) Survey has been used to analyze students in introductory calculus-based physics, introductory math-based astronomy, upper division/graduate-level physics, as well as Turkish students in high school and introductory university physics. In this study, we consider post-test survey results from pre-IPLS introductory algebra-based physics course sections in 2019 and 2020, which are predominately life science majors. The following variables will be checked for statistical relationship: 1) students' self-reported learning goals in introductory algebra-based physics courses; 2) students' choice of major (in particular, life science majors dominate the student population). From prior studies regarding these two variables, it is anticipated that life science majors that express a mastery learning goal (as opposed to a performance learning goal or otherwise) may have more expert-like views than other students; discussion will focus on the accuracy of this statement and potential explanations for results.

PAR-G.05: 10:00-11:00 a.m. Putting Biology into Biophysics: Adventures in Co-Teaching with Life Scientists

Invited – Kristine Lang, Colorado College, Colorado Spgs., CO 80903-3243

The life sciences present a rich trove of physics problems to ponder and solve. However, a challenge I faced in teaching the physics of biological topics is that, as a physicist, I don't know very much biology. To address this challenge, I developed and co-teach two life-science oriented physics courses in collaboration with biologists. In collaboration with a molecular biologist, I teach a research-based course for first-year students focusing on modalities of microscopy including fluorescence and atomic force microscopy. In collaboration with a human biology and kinesiology professor, I developed and co-teach a 100-level science requirement course focusing on human athletic performance. In this talk I discuss several of the activities and labs developed from these collaborations. I also discuss the rewards and the challenges of teaching with life science colleagues.

PAR-G.05: 10:00-11:00 a.m. Scaffolding Student Mechanistic Reasoning About Static and Dynamic Liquids

Poster – Dawn Meredith, University of New Hampshire, Durham, NH 03824

Jason H. Jung, Physics Department, University of New Hampshire, Durham

Daniel E. Young, University of North Carolina, Chapel Hill

James Vesenka, University of New England

The kinetic theory of gases provides a powerful set of mechanistic resources that allows students to reason productively about pressure in gases. We give evidence students (and experts) are lacking similar resources for reasoning about liquids (especially water in an IPLS course), and provide initial evidence of some possibly productive resources.

PAR-G.05: 10:00-11:00 a.m. Science 100 – The Science of Energy

Poster – Donald G. Franklin, Retired, Hampton, GA 30228-2932

Using Energy to Teach Science for all students. This course allows students to learn about the Science of Energy. It contains information on Energy of Biology, Chemistry, Earth & Space, Physics. This gives students a background in all Sciences while in high school. It is designed to help small high schools, and limited expenditures for science courses in high schools. The Science of Energy helps teachers who have limited experience in all sciences to develop a curriculum that all students can learn and prepare, not just AP courses.

PAR-G.05: 10:00-11:00 a.m. Teaching IPLS Students to Use Math in Science*

Invited – Edward Redish, University of Maryland, College Park, MD 20742-4111

IPLS students and students in algebra-based physics often see math as a as a calculational tool rather than a way of reasoning about the physical world. But, in physics, math-in-science plays a critical role both in our physical ontology ("What is an E-field, really?") and epistemology ("I derived this result from a true equation so it must be true.") as well as for reasoning and organizing our conceptual knowledge. The critical conceptual blending* of physical concepts with mathematical symbology is rarely taught in math and is often taken for granted in physics. I identify a series of tools (epistemic games**) that can help students learn to connect math to the physical world. These tools include readings and activities that can be used throughout a class and that can be downloaded from the Living Physics Portal*** and integrated into existing classes.

*Work supported in part by US NSF grants 1504366 and 1624478. * G. Fauconnier & M. Turner, How We Think (Basic Books, 2002) ** A. Collins and W. Ferguson, Educational Psychologist 28:1 (1993) 25-42., J. Tuminaro and E. F. Redish, *Phys. Rev. STPER*, **3**, 020101 (2007) *** https://www.livingphysicsportal.org

PAR-G.05: 10:00-11:00 a.m. Three-Dimensional Learning in Introductory Physics for Life Sciences Laboratory Courses

Poster – Jason M. May, University of Utah, Salt Lake City, UT 84112

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

Recent developments in Introductory Physics for Life Sciences (IPLS) laboratory courses have produced fruitful curricular and pedagogical shifts in undergraduate physics education. However, less work has examined to what extent these developments align with a parallel growing interest in three-dimensional learning, which is widely being implemented at the K-12 level through the Next Generation Science Standards. This poster presents a preliminary analysis of a newly reformed IPLS laboratory course at the University of Utah and its extrapolation of three-dimensional learning that involves scientific practices, disciplinary core ideas, and crosscutting concepts. Results suggest IPLS lab curriculum prompts students to engage in complex and dynamic scientific practices and utilize crosscutting concepts when conducting laboratory experiments to meet IPLS-specific course performance expectations. This poster presents course learning outcomes, laboratory experiments, and student artifacts to highlight three-dimensional learning within these IPLS laboratory courses and discusses the potential benefits inherent in developing this new approach.

PAR-G.05: 10:00-11:00 a.m. Understanding COVID-19 by Modeling It

Poster – Peter Hugo Nelson, Guilford College, Greensboro, NC 27410

Simple epidemiological models are introduced using finite difference methods in Excel. The SIR model explains the initial exponential growth of COVID-19, the effects of social distancing in the US during early April 2020 and successfully predicts the continued spread of the virus during late April and May 2020. The SIR model is the origin of the basic reproduction number R0 and herd immunity. It also predicts what will happen if social distancing is lifted prematurely. A wide range of student research projects are possible for modeling and making predictions based on real data for US states and other countries. See http://circle4.com/biophysics for free sample chapters and videos.

Session PAR-G.06 PER: Student Content Understanding, Problem-Solving and Reasoning IV

Wednesday, July 22, 10:00–11:00 a.m. Sponsor: AAPT

WEDNESDAY

PAR-G.06: 10:00-11:00 a.m. Brief Concept Survey of Units/Unit Systems in Introductory Physics Abstract

Contributed – Nathaniel Amos, Florida Gulf Coast University, Fort Myers, FL 33912

David Harris, Jeff Hutchinson, Florida Gulf Coast University

Proficiency in units/dimensional analysis is a useful skill in the sciences and engineering, and STEM instructors often presume competence from their students in this area. However, unit analysis techniques and unit systems are not always formally taught, and even with explicit emphasis during instruction, many students lack the repeated exposure necessary to master them. To assess student understanding of units and unit systems, we administered a brief, itemized survey to N=53 calculus-based introductory university physics students. The survey was intended to uncover possible misconceptions and identify previously unknown obstacles to student success within this topic. Our results suggest that as many as half of surveyed participants may not recognize the adaptability of symbolic physical equations to different unit systems. Furthermore, a similar proportion failed to eliminate non-viable answer choices involving analytic functions with units inside their arguments. Consequently, we believe units/dimensional analysis is a topic ripe for further investigation.

PAR-G.06: 10:00-11:00 a.m. Framework for the Natures of Covariational Reasoning in Introductory Physics

Contributed – Alexis RW Olsho, University of Washington, Seattle, WA 98195-0001

Charlotte Zimmerman, Suzanne White Brahmia, University of Washington

Covariational reasoning--how a change in one quantity is related to a change in another quantity (e.g., a 1/r potential, or the exponential decay with time of a charged capacitor)--is integral to how scientists model the physical world. It is also a skill we expect students to develop as a result of introductory physics instruction. Little research has been done to characterize physics experts' covariational reasoning. Our research suggests that physics experts use a number of strategies--distinct from those of mathematics experts--that optimize thinking about physical quantities and how they relate to each other. We present a framework that describes physics expert covariational reasoning in introductory-level physics contexts as an important first step toward an understanding of students' covariational reasoning, how students' covariational reasoning changes over the course of physics instruction, and how instruction can be designed to help develop this important type of reasoning.

PAR-G.06: 10:00-11:00 a.m. Impact of Peer-Led Recitation Sections in Introductory Physics

Contributed – Rebecca Forrest, University of Houston, Houston, TX 77062

Jacqueline Hawkins, Donna Pattison, Monica Martens, Shuo Chen, University of Houston

Peer-led recitation sections were implemented in introductory algebra-based physics courses to improve student success. Recitation attendance is required depending on student’s score on a diagnostic exam taken during the first two weeks of class. Recitations are led by two undergraduate Peer Facilitators, limited to about 25 students per section, and focus on problem-solving in small groups. An analysis of 2,738 students in first semester introductory algebra-based physics courses shows a positive correlation between recitation attendance and final exam score for the targeted students. Recitation structure and analysis results will be presented.

PAR-G.06: 10:00-11:00 a.m. Insights into Student Understanding of Statistical Mechanics

Contributed – William C. Lo, North Carolina State University, Raleigh, NC 27606

As part of our effort to develop a concept inventory for statistical mechanics, we have interviewed a number of students who have taken a thermal physics course, at both the undergraduate and graduate level, about their understanding of the statistical mechanics topics taught in the thermal physics curriculum. The questions asked during the interviews were formulated with input from experts in the field, and will later be fleshed out into multiple-choice questions. Here, we report some of our intermediate findings about the students understanding of some of the topics.

PAR-G.06: 10:00-11:00 a.m. Investigating the Role of Cognitive Reflection in Following Reasoning Chains*

Contributed – Beth A. Lindsey, Penn State Greater Allegheny, McKeesport, PA 15132

Werner W. Hager V, Penn State Greater Allegheny

MacKenzie R. Stetzer, University of Maine

As part of a multi-institution collaboration, we are investigating the efficacy of educational interventions rooted in dual-process theories of reasoning (DPToR). In prior work, we examined the extent to which students are able to follow and infer conclusions from reasoning chains that have been provided to them. In order to explore this issue, we developed a collection of tasks that are administered online to large populations of students in introductory calculus-based courses. We have previously reported that students who themselves respond correctly to the base task will be more likely to follow the correct reasoning chain provided. In this talk, we examine the factors that influence students to set aside their own reasoning and adopt correct reasoning when it is shared with them. The relation of our findings to DPToR, and the implications of our results for instruction and curriculum development will be discussed.

* This material is based upon work supported by the National Science Foundation under Grant Nos. DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, and DUE-1821561.

PAR-G.06: 10:00-11:00 a.m. Scaffolding Student Exploration of Alternative Approaches*

Contributed – MacKenzie R. Stetzer, University of Maine, Orono, ME 04469-5709

Ryan P. Moyer, University of Maine

J. Caleb Speirs, University of New England

Beth A. Lindsey, Penn State Greater Allegheny

Mila Kryjevskaia, North Dakota State University

A growing body of research in physics education indicates that the nature of human reasoning itself may impact student performance on physics questions. Analysis of student reasoning patterns through the lens of dual-process theories of reasoning (DPToR) suggests that students may struggle to engage analytical processing productively when responding to a physics question that contains salient distracting features. As part of a larger effort to investigate and support student reasoning in physics, we have used reasoning chain construction tasks in order gain insight into students’ initial perceptions of viable approaches for solving a qualitative physics question and to examine the impact of guiding students to explore alternative approaches before revisiting that physics question. In this talk, preliminary results will be presented and implications for research-based curriculum development aligned with DPToR will also be discussed.

*This material is based upon work supported by the National Science Foundation under Grant Nos. DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, and DUE-1821561.

PAR-G.06: 10:00-11:00 a.m. Shift Toward Scientific Reasoning in the Introductory Physics Lab

Contributed – John R, Walkup, California State University, Fresno Fresno, CA 93740

Roger Key, Avery Sheldon, California State University, Fresno

Michael A. Walkup, University of Oklahoma

The authors present samples of a complete lab sequence developed for introductory physics labs that target industrial statistical analysis and scientific reasoning as primary learning objectives. This shift in approach replaces traditional verification of lecture content with the more industrial practice of estimating unknown values through statistics and error analysis. These activities place students in the role of lab designers, using data-driven decision making -- which is explicitly taught -- to optimize lab procedures. Most importantly, the learning objectives for each lab are tailored to generate a broad range of skills developed incrementally throughout the semester. Four of the activities developed for the sequence garnered publication in refereed physics education journals, with one representing a Course-Based Undergraduate Research Experience (CURES) activity. Benefits include a tightened adherence to ISO and NIST definitions and procedures, reduced equipment demands, a heightened career focus, and explicit instruction in writing.

PAR-G.06: 10:00-11:00 a.m. Similarities and Differences between Unprompted and Prompted Student-generated Diagrams

Contributed – Michael Vignal, University of Colorado Boulder, Boulder, CO 80309-0390

Bethany R. Wilcox, University of Colorado Boulder

Diagraming physical scenarios is ubiquitous in physics problem solving and a key focus of physics education. In this talk, we discuss and compare unprompted and prompted diagrams generated by 19 physics majors (ranging from lower-division to graduate students) during one-on-one problem-solving interviews. These interviews included multiple-choice introductory-level physics problems (that neither contained nor asked for diagrams) followed by explicit diagraming tasks for similar scenarios. We discuss patterns and surprises in student-generated diagrams as well as implications for instruction and assessment.

PAR-G.06: 10:00-11:00 a.m. Student Reasoning About Integration of Charge Density

Contributed – Paul van Kampen, Dublin City University, Dublin, 9 Ireland

Leanne Doughty, Georgetown University

Charge distributions provide an early example where students need to apply integration, first encountered in a calculus course, in a physics context. Where mathematics courses typically focus on techniques for finding antiderivatives, in physics courses both the function (say the linear charge density) and the product of the function at a point and the differential of the integrating variable (say the infinitesimal length) tend to have physical meaning (the charge on that length). We have investigated responses of students to different questions about charge density. We asked them to describe how they would obtain the total charge on a nonuniformly charged rod, to interpret definite integrals of the linear charge density in the context of a charged rod, and to calculate the charge on a rod or disk for a given charge density distribution. We have identified a number of inconsistencies in students' reasoning and explore possible reasons for these.

PAR-G.06: 10:00-11:00 a.m. The Associations Between Conceptual Learning, Physics Identity and Social Interdependence

Contributed – Miguel Rodriguez-Velazquez, Florida International University

Geoff Potvin Florida International University

This study takes place in a Modeling Instruction Introductory Physics I course and investigates whether students' social interdependence experiences are associated to semester-long conceptual and physics identity gains. In Modeling Instruction students spend the majority of class time working in small groups leading to varying levels of task and outcome interdependence with other group members. Detailed data were collected to measure pre to post conceptual and identity gains as well as their reported task and outcome interdependence for each of their assigned groups. Students' individualism and cooperation beliefs were also collected as they have been shown to be correlated with social interdependence. Using the mean of students' task and outcome interdependence throughout the course, linear regressions were conducted to find correlations with the pre to post semester differences in students' conceptual and physics identity. A significant shift in student's pre to post semester cooperation beliefs was also observed.

PAR-G.06: 10:00-11:00 a.m. Transfer from Discrete to Continuous Inner-Products in a Computational Course

Contributed – Christian D. Solorio, Corvallis, OR 97331

David Roundy, Corinne Manogue, Oregon State University

Because a "spins-first" approach is becoming a more common method of teaching quantum mechanics, we want to know how the knowledge of discrete spin systems might help student's understanding of continuous quantum systems. Leveraging computation, where wavefunctions are necessarily discretized, is a promising strategy of exploring this. During the junior-year of Oregon State University's physics curriculum, students take a computational lab course in parallel with the "spins-first" lecture course. In this computational lab, students solve quantum problems by pair-programming in Python. We observed three pairs of students in class while they worked on a computational task of taking inner products of wavefunctions and basis states. In this talk, we will discuss the concepts of inner products students transferred from the discrete case used in the lecture course to the continuous case used in the computational lab and how they implemented these mathematical and physical concepts into their code.

Session PAR-G.07 PER Using Institutional Data Sources and Big Data Research Methods Wednesday, July 22, 10:00–11:00 a.m.

Sponsor: Committee on Research in Physics Education Co-Sponsor: Committee on Physics in Undergraduate Education

PAR-G.07: 10:00-11:00 a.m. "Big Data" Analysis of Postsecondary Student Engagement and Performance: Insights and Perils

Invited – Jacquelyn J. Chini, University of Central Florida, Orlando, FL 32816

Adan Vela University of Central Florida

Shahab Boumi University of Central Florida

Institutions record multi-faceted data about student identity, engagement and performance, from family income and zip code to "check-ins" at the campus gym to course enrollment and performance. This data could help us identify systemic barriers to students' engagement and degree completion and describe the enrollment strategies of successful students. However, because the data is often de-identified, it does not tell the complete story of a student's journey through their degree program. In this talk, I will describe the questions and methods our team has explored, as well as the challenges that have arisen in interpreting the data and results.

PAR-G.07: 10:00-11:00 a.m. Extending Machine Learning to Predict Unbalanced Physics Course Outcomes

Invited – Jie Yang, West Virginia University, Morgantowm, WV 26506

Seth DeVore, West Virginia University

Machine learning algorithms represent an exciting new class of quantitative methods to understand physics classes and students. Recent work has applied these algorithms to classify students as those likely to receive an A or B or students were likely to receive an C. D, F in a physics class. The metrics used become unreliable when the outcome variable is substantially unbalanced. This talk further explores the classification and extends those methods to predicting whether a student will receive a D or F. This study also investigated the previous finding that demographic variables such as gender, underrepresented minority status, and first-generation status had low variable importance for predicting class outcomes; down sampling revealed that this result was not due to the underrepresentation of these students in the class studied.

PAR-G.07: 10:00-11:00 a.m. What do Grades Tell Us About Students, Instructors, and Programs?

Invited – Andrew F. Heckler, The Ohio State University, Columbus, OH 43210

Course grades are concrete outcomes with real-world consequences for students. To what extent do grades, as they are currently awarded, achieve our instructional and programmatic goals and reflect our values? Higher Educational Institutions are sitting on vast amounts of data that can help us to gain more insight into these questions and perhaps lead us to more desired outcomes. I will discuss three data analytics projects we conducted—based on data from over 5 years and 20,000 students-- to provide examples. First, to set context, we characterize grade outcomes in introductory physics courses, including ACT scores, age, and several demographic groupings. Next we examine the effects of individual instructors on student grades in their own courses, and the grades of their students in follow-on courses. Finally, we examine grade components and find moderate demographic differences between various components, suggesting that various grade components and grade-weighting may benefit from reconsideration.

Session PAR-G.08 PhysTEC: Building Institutional Support and Leadership for Teacher Preparation

Wednesday, July 22, 10:00–11:00 a.m. **Sponsor: Committee on Teacher Preparation** **Presider:** *Monica Plisch*

PAR-G.08: 10:00-11:00 a.m. Attracting STEM-Talented Undergraduates to Secondary Education with Early Teaching Experiences*

Contributed – Nicole Gugliucci, Saint Anselm College, Manchester, NH 03102-1310

Kelly Demers, Saint Anselm College

We investigated how participation in a semester-long after-school teaching experience attracts undergraduate STEM majors to consider a career in teaching. The students were asked several questions about their attitudes towards teaching in high-need districts before and after the experience through surveys and interviews. Preliminary analysis suggests that experience with teaching in this program does lead STEM majors to consider teaching as a career. However, our sample was not ideal, since students typically need to declare their second major in secondary education in their sophomore year in order to fit all of the course requirements in four years. The strong interest in teaching as a career among graduating seniors was striking and leads us to conclude that earlier intervention with a teaching experience could spark interest in teaching in time to add the secondary education major, thus ensuring that the students are well prepared upon entering the classroom.

*This work was funded by NSF Noyce Award #1758227

PAR-G.08: 10:00-11:00 a.m. Building Institutional Support: Lessons Learned from Two Physics Sites

Invited – John Stewart, West Virginia University, Morgantown, WV 26506

Gay Stewart, West Virginia University

Successful programs build support among department colleagues and university administration. Ideally building a teacher preparation program begins with institutional commitment before the first proposal is written. University strategic plans often include sentiments like: “Enhance our ability to recruit new students of excellent quality and support their success” and “Provide students the tools for success in the job markets of the future.” Showing your efforts are aligned with administrative priorities is necessary to ensuring institutional support. Department support is also easier to gain and maintain when teacher preparation is cast in terms of departmental priorities such as an improved undergraduate program and significant positive attention from administration. Related efforts around launching two PhysTEC programs will be discussed.

PAR-G.08: 10:00-11:00 a.m. PhysTEC at Virginia Tech, Leadership in Action

Invited – John Simonetti, Virginia Tech, Blacksburg, VA 24060

The PhysTEC program at Virginia Tech utilizes an effective collaboration, and division of labor, between the Physics Department and the School of Education. In the Physics Department students receive their content knowledge, acquiring a BS or BA in Physics. And they have early teaching experiences which provide moral sustenance to the students who have decided to pursue teaching, but also help some students to realize they wish to pursue teaching. These experiences include partaking in Physics Outreach, the Physics Teaching and Learning course, and the Physics Learning Assistant Program. With their BS/BA, our majors can then obtain a Masters of Education (MAEd) degree, in the School of Education. While they pursue their MAEd, the Physics Department financially supports these students as teaching assistants in Physics. This last aspect of our program is particularly important to our recruitment and production of physics teachers.

PAR-G.08: 10:00-11:00 a.m. Using the SPIN-UP Report and UTeach to Revitalize Teacher Education

Invited – Bruce Palmquist, Central Washington University, Ellensburg, WA 98926-7422

In 2012, Central Washington University became a PhysTEC supported site. The success of our project relied on us strengthening our partnerships with other STEM departments as well as our existing science teacher education program. Along with the PhysTEC project, the physics department was in the middle of a pedagogical revitalization using the results of the SPIN-UP report (1). Curriculum revisions such as integrated lecture-lab courses, mentored inquiry projects for all majors, and a learning assistant program lifted the physics department to a position of pedagogical leadership on campus. The department worked with pedagogical experts in mathematics and other science departments to translate some of these innovations to their content and pedagogy courses. This broader collaboration attracted the attention of two deans and the provost, leading the College of the Sciences and the College of Education and Professional Studies to overhaul STEM teacher education by revising and implementing the UTeach model.

(1) R. C. Hilborn, R. H. Howes, K. S. Krane, eds., Strategic Programs for Innovations in Undergraduate Physics: Project Report (American Association of Physics Teachers, College Park, MD, 2003). https://www.aapt.org/Programs/projects/spinup/upload/SPIN-UP-Final-Report.pdf

WEDNESDAY

Session PAR-G.09 Rethinking the Boundaries of the Laboratory Classroom

Wednesday, July 22, 10:00–11:00 a.m.

Sponsor: Committee on Laboratories Co-Sponsor: Committee on Physics in Undergraduate Education

PAR-G.09: 10:00-11:00 a.m. Connecting Physics and Engineering Through a Modernization of the Advanced Physics Laboratory Curriculum

Invited – J. Archibald Peters, Chicago State University, Chicago, IL 60628-1598

Mel Sabella, Austin Harton, Russell Ceballos, Justin Akujieze, Chicago State University

The current environment in the STEM workforce is one of unprecedented challenges and opportunities, demanding innovation and leadership skills. Current students must be forward-thinking to solve grand challenges and take advantage of diverse opportunities. To thrive in this workforce, students need a robust STEM curriculum that focuses on traditional and modern perspectives to address science and engineering applications. The goal of this project is a complete modernization of the advanced laboratory curriculum for our physics and engineering-physics students. The project has outcomes that include: 1. Outlining a curriculum plan for the modernization of our applied physics/engineering laboratory with the inclusion of modern equipment, applications, and new experimental Learning Lab modules 2. Establishing a student learning community that will inform instructional revisions by incorporating student input through the use of the Learning Assistant Program. 3. Providing outreach opportunities for increasing STEM interest by utilizing the student-developed modules at local high schools.

PAR-G.09: 10:00-11:00 a.m. Constructing Physical and Experimental Models in Upper-Division Lab Courses

Invited – Laura Ríos, California Polytechnic State University, San Luis Obispo, San Luis Obispo, CA 93407-0404

Recently, discourse on the role of laboratory courses asks “What are labs for?” Notably, there does not appear to be an equivalent discourse for lecture-based content or courses. When data show small or null gains on learning assessments for theory courses, we innovate in these courses; we do not throw them away. I embrace a similar orientation of investment and innovation in lab courses. In this talk, I will discuss how I have begun to transform my research practices align with this orientation towards lab courses by focusing on a specific project. My current research involves uncovering how students begin to construct models during their upper-division modern physics lab sequence. Using the Modeling Framework for Experimental Physics as a theoretical foundation, the lab’s evaluative tools lab focus on how students use physical principles combined with experimental assumptions or simplifications to gain a deeper conceptual understanding of the experiments they endeavor.

PAR-G.09: 10:00-11:00 a.m. Even My Robots Are Non-Binary: Questioning Borders of Ideas and Land

Invited – Mylene DiPenta, Nova Scotia Community College, Nova Scotia B4N0A6 Canada

What helps students transfer ideas between labs, lectures, non-school projects? Why are students in my electronics lab so angry that there is no clear border between “conductor” and “insulator”? I’m experimenting with creating connections between ideas by making play-dough circuits, teaching metrology, and analyzing assumptions about borders. Borders as binary and absolute took hold ~500 years ago, alongside the scientific revolution. So did the rise of the nation-state, narrowing of gender roles, criminalization of same-gender sex, invention of race and white supremacy, creation of policing and prisons, and of course colonialism. Science, along with many other disciplines, suddenly became more centrally controlled and rigid in its borders. What can each of these borders teach us about the others? What could non-binary borders look like, and how do they affect lab learning and teaching? Please join us if you are interested in informal science, laboratory assessment, gender fluidity, colonialism, or of course non-binary robots.

PAR-G.09: 10:00-11:00 a.m. Letters Home: Transcending the Boundary Between Lab and Family/Friends

Invited – Charles L. Ramey II, Texas Tech University, Lubbock, TX 79409-4349

Communication is an important skill in all fields of STEAM learning environments, including physics lab courses. The AAPT Recommendations for the Undergraduate Physics Curriculum identify ‘communicating physics’ as one of six major learning outcome focus areas for undergraduate physics labs. But, to whom? Traditionally, physics classrooms (including labs) are a black-box where the learning process is shrouded from stakeholders such as policymakers, practitioners, and families. My research investigates the pedagogical method Letters Home (Lane, 2014), which provides students with the opportunity to communicate beyond the borders that constrain practical lab reports. In my implementation, the Letters Home method tasks students with writing letters to a non-physicist then gradually to a graduate student or a physics professor. We used the AAPT Recommendations to inform development of a coding scheme. However, the recommendations still contain ‘communicating physics’ within the boundaries of a black-box. In this talk, I will present about my implementation of Letters Home as a foothold into exploring the question, How can we develop writing activities that extend beyond the traditional borders of the classroom and communicate with all stakeholders? Lane, W. B. (2014). Letters home as an alternative to lab reports. *The Physics Teacher*, **52**(7), 397-399.

Session PAR-G.10 Technologies

Wednesday, July 22, 10:00–11:00 a.m. Sponsor: AAPT

PAR-G.10: 10:00-11:00 a.m. Measurement Uncertainties

Contributed – Kris Lui, Montgomery College, Germantown, MD 20876

One aspect of data analysis that seems overlooked in introductory lab instruction is that of measurement uncertainties. Students have difficulty grasping the concept that measurements are not infinitely precise. In this talk, I will outline an activity and follow-up methods to instill the idea of measurement uncertainty in an introductory college-level lab setting.

PAR-G.10: 10:00-11:00 a.m. Small Force Project for Teaching Statistical Analysis in the Lab

Contributed – Nathan D. Powers, Brigham Young University, Provo, UT 84602

Robert Davis, Brigham Young University

Statistical analysis is one of the technical skills we are targeting in a newly developed project-based lab course. Students are asked to measure the smallest possible force using a strain gauge and to provide convincing evidence that the force has been detected. This goal extends over several class periods as students make revisions to improve their measurements and complete pre-lab readings and activities on statistical analysis methods. At the culmination of the module, students design and conduct an experiment that requires the measurement of a small force. They must use the statistical methods they have learned to support their findings.

PAR-G.10: 10:00-11:00 a.m. The Physics of a Yoyo Using a Smartphone

Contributed – Martin Monteiro, Universidad ORT, Uruguay

Isabel Salinas, Universidad Politécnica de Valencia

Juan Antonio, Monsoriu Universidad Politécnica de Valencia

WEDNESDAY

Arturo C. Martí, Facultad de Ciencias, Universidad de la República

The usage of toys to teach physics is an interesting approach to promote engagement and creativity. Traditionally, toys have been widely used in qualitative demonstrations. However, it is frequently difficult to extract quantitative results in physics experiments involving toys. One possible strategy to address this difficulty is the use of smartphone sensors. In this work we investigate the dynamics of a traditional toy, the yoyo, theoretically and experimentally, using smartphone' sensors. In particular, using the gyroscope, the angular velocity was measured. The experimental results were complemented thanks to a digital video analysis. As the yoyo is a ubiquitous, simple and traditional toy this simple proposal could encourage students to experiment with everyday objects and modern technologies. More information: http://smarterphysics.blogspot.com/

PAR-G.10: 10:00-11:00 a.m. Treatment of Statistics and Error in Introductory Physics Lab Manuals

Contributed – Jimmy Gonzalez, University of California at Merced, Merced, CA 95343

John R. Walkup, California State University, Fresno

Many students experience their first practical application of statistics and error analysis in their introductory physics laboratory courses. The activities they conduct in their lab courses teach definitions, concepts, and skills in statistics and error analysis that they will use for the rest of their academic and postgraduate career. We analyze the use of statistical methods in college-level introductory physics laboratory courses by reviewing a sample of student lab manuals collected from two-year community colleges and four-year universities. Approaches to introducing statistical concepts and procedures are examined for consistency, with particular reference to national and international statistical guidelines such as the National Institute of Standards and Technology (NIST) and the International Organization for Standardisation (ISO). Our analysis reveals a severe inconsistency in the treatment of statistics and error among the sampled lab manuals for courses aimed at science and engineering students.

Session PAR-G.11 Upper Division/Graduate Courses

Wednesday, July 22, 10:00–11:00 a.m. Sponsor: AAPT

PAR-G.11: 10:00-11:00 a.m. Advanced Students' and Faculty Members' Reasoning about the Double-slit Experiment with Single Particles

Contributed – Ryan T. Sayer, Bemidji State University, Bemidji, MN 56601

Alexandru Maries, 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 question 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 thoughtful responses to the more speculative question related to the double-slit experiment with single particles, which shed light on what it means to think like a physicist. Student responses varied greatly in their correctness and sophistication of reasoning, suggesting that while some advanced undergraduate and graduate students had begun to think like a physicist in the challenging quantum mechanical contexts of the problems posed, others needed additional guidance and scaffolding support in order to develop expert-like reasoning skills.

PAR-G.11: 10:00-11:00 a.m. Astronomical Spectroscopy for Upper-Division Labs

Contributed – Savannah M. Lyons, Saginaw Valley State University, Saginaw, MI 48601*

Christopher Nakamura, Joseph Bruessow, Saginaw Valley State University

Upper-division lab courses typically focus on modern physics ideas. The experiments usually address topics in atomic, molecular, optical and solid-state physics well. However, they often lack astronomy/astrophysics experiments, particularly at institutions without dedicated on-campus observatories. These subfields are of significant interest to students, and continue to be important areas of research, so relevant labs are desirable. In this project, we explored astronomical spectroscopy measurement with the aim of incorporating it into an upper-division laboratory curriculum. The focus was on inexpensive, portable equipment. Our primary interest was in measuring the red shift of highly red-shifted quasars, which are of interest in cosmology, particularly with respect to measuring the Hubble constant. Additionally, we have measured stellar spectra, primarily as a means of calibration, but also to explore the possibility of connecting to stellar astrophysics. In this talk we present results of these investigations and discuss possibilities for implementation.

PAR-G.11: 10:00-11:00 a.m. Demonstration to Show Resonant Oscillations of a Simple Pendulum

Contributed – D. Blane Baker, William Jewell College, Liberty, MO 64068-1896

One of the ubiquitous problems in classical mechanics is that of a simple pendulum attached to a support that oscillates in time. Under certain conditions, such a pendulum can be modeled as a driven harmonic oscillator, and, as a result, the pendulum can undergo large-amplitude oscillations when the driving frequency of the oscillating support matches the natural frequency of the pendulum. To accompany analysis of this problem in mechanics courses, a simple apparatus has been built to model the system described above. The apparatus will be presented, along with a Lagrangian mechanics analysis of the motion. In addition, several other applications of the demonstration will be discussed.

PAR-G.11: 10:00-11:00 a.m. Improving Student Understanding of Dirac Notation by Using Analogical Reasoning in the Context of a Three-Dimensional Vector Space

Contributed – Emily M. Marshman, Community College of Allegheny County, Pittsburgh, PA 15212-6097

Chandralekha Singh, University of Pittsburgh

We discuss an investigation of student difficulties with Dirac notation in the context of a three-dimensional vector space and the validation and evaluation of a Quantum Interactive Learning Tutorial (QuILT) to improve student understanding of these concepts. We find that many upper-level undergraduate students in quantum mechanics courses have difficulties with Dirac notation even in the context of a three-dimensional vector space after traditional instruction. The QuILT uses analogical reasoning and builds on students' prior knowledge of three-dimensional vectors in the familiar context of introductory mechanics to help students build a coherent understanding of Dirac notation in three dimensions before transitioning to the quantum mechanical context. We summarize the development of the QuILT and findings from its evaluations. We thank the National Science Foundation for support.

PAR-G.11: 10:00-11:00 a.m. Micropattern Gas Detectors for Advanced Physics Laboratories

Contributed – Shawn Zaleski, North-Rhine Wes 52074 Germany

Kerstin Hoepfner, RWTH University

Micropattern gas detectors (MPGDs), of which gas electron multipliers (GEMs) are a class, are a recent technology meeting today's higher requirements of both spatial and temporal resolution in high energy physics, as well as medical applications. GEM chamber performance depends on many different parameters such as gain, gas tightness, high voltage (HV) response and noise. The gain is a key parameter, a measure of the chamber's ability to amplify an electronic signal from ionizing particles passing through the chamber's gas volume. Students in the RWTH Aachen University advanced physics lab studied the effect on gain while varying gas mixture and HV, as well the incoming particle rate. This experiment allows the instructor to cater to diverse set of applications and student interest. Student feedback will be presented.

PAR-G.11: 10:00-11:00 a.m. Preparing for the Quantum Revolution – The Role of Higher Education

Contributed – Michael Fox, JILA, University of Colorado Boulder JILA, Boulder, CO 80309

Benjamin M Zwickl ,Rochester Institute of Technology

Heather J. Lewandowski, JILA and University of Colorado Boulder

Since the passing of the National Quantum Initiative Act in December 2018, there has been great interest from business, academia, and the general public in the quantum industry. Faculty at higher-education institutes, mainly in physics, engineering, and computer science departments have been struggling with the question of how to adapt their courses to meet the demands of students interested in this exciting new field, ensuring that the content delivered would be relevant to possible future careers, whilst also maintaining academic relevance. Results from an interview study of 21 companies in the quantum industry will be presented, illustrating the skills and knowledge present in the workforce of the quantum industry; how those skills and knowledge relate to existing courses and training; and where there are opportunities for new and innovative course development.

PAR-G.11: 10:00-11:00 a.m. Strategies for the Math Physics Course at TLU

Contributed – Calvin J. Berggren, Texas Lutheran University, Seguin, TX 78155

A course in mathematical methods for physics is a valuable course in many physics departments to build a bridge between introductory courses and demanding upper-division courses, yet there are a number of challenges in successfully implementing such a course. After designing a math physics course from scratch and refining it over the last six years, I will discuss strategies for the course relating to content coverage, level of rigor, grading scheme, textbook selection, integration of conceptual thinking, and use of software.

PAR-G.11: 10:00-11:00 a.m. What Is 'Parametric Drive' of a Simple Harmonic Oscillator?

Contributed – David A. Van Baak, TeachSpin, Inc., Buffalo, NY 14214

Students know that a simple harmonic oscillator (SHO) has a 'resonance curve', and some students even know how to label the axes of a plot showing that resonance curve. The frequency (and amplitude) of a sinusoidal drive force are the main independent variables, and the steady-state amplitude of the SHO's response is the main dependent variable. But a simple modification to a mechanical SHO can change it from 'direct drive' to 'parametric drive', and this subtle change has dramatic consequences. First of all, parametric resonance occurs when the drive frequency is not at the SHO's natural frequency, but nearly "double" that frequency. Next, there no longer emerges any steady-state amplitude of response, and the right dependent variable to measure is the rate of "exponential growth" (or decay) of the system's oscillations. There is also a "threshold amplitude" for the drive required to give any growth in the response. This presentation features a torsional SHO with a non-contact parametric drive, and shows theoretical predictions and experimental data for its performance. Finally, we connect this parametric drive of a mechanical SHO to some glamorous applications of parametric excitation in modern physics.

Labs/Apparatus II

PS-B.01: 12:30-1:30 p.m. A Lab Skills Diagnostic Test

Poster – John W. Zwart, Dordt University, Sioux Center, IA 51250

AAPT (in https://www.aapt.org/resources/upload/labguidlinesdocument_ebendorsed_nov10.pdf) recommends that physics majors have proficiency in the following lab skills: constructing knowledge, modeling, designing experiments, analyzing and visualizing data, and communicating physics. I have developed a brief multiple-choice questionnaire to assess incoming students' lab skill level in these areas. It was administered as both a pre-test and post-test for the first semester of introductory calculus-based physics. Preliminary results indicate that little improvement on the skills tested occurs without explicit instruction.

PS-B.01: 12:30-1:30 p.m. Image-Charge Effects on the Electrostatic Deflection of a Charged Pendulum Bob

Poster – Hasan A. Tekalp, Quinnipiac University, Handen, CT 06518

Douglas S. Goodman, Robert D. Fischetti, Alex R. Hodges, Quinnipiac University

A charged pendulum deflected by a uniform electric field and held in mechanical equilibrium is a commonly discussed thought experiment in introductory courses on electricity and magnetism. The uniform electrical and gravitational force fields cause the pendulum's small-angle deflection to be linearly proportional to its net charge and the strength of the electric field. For the purpose of creating a laboratory exercise, we constructed an apparatus inspired by the thought experiment and investigated the relationship between the equilibrium deflection, the charge on the pendulum, and the strength of the electric field. The apparatus consists of a charged pendulum bob suspended by an insulating string between two energized parallel metal plates. In contrast to the canonical solution, we find that the deflection at small angles depends non-linearly on the pendulum's charge and electric field strength. Furthermore, if the pendulum has enough charge, then no equilibrium is observed, and the pendulum continues to deflect until it hits a plate. We successfully model the observed equilibrium deflection by including the non-uniform field contribution from the infinite series of image charges associated with a point charge between a pair of parallel plates.

PS-B.01: 12:30-1:30 p.m. Measuring the Speed of Light

Poster – Rebekka Frøystad, Niels Bohr Institute, Copenhagen, 2100 Denmark

Ian G. Bearden, Niels Bohr Institute

We have developed a lab for measuring the speed of light (c) aimed at high school students. Light is emitted from an LED to a beamsplitter, where part of the light is reflected to a monitor. The rest hits a reflector and upon returning to the beamsplitter is reflected again and measured by another monitor. By increasing the distance between the beamsplitter and the reflector, the time difference between the signals can be measured and c extrapolated from performing a linear regression on the measurements. A class will typically arrive at a value within a 3% deviation from that theoretically given. To perform the experiment, the only prior knowledge needed is the definition of velocity. This allows students of a physics class with different levels of understanding to participate in an experimental program that both gives practical experience handling electronic equipment and teaches the importance of making consistent measurements.

PS-B.01: 12:30-1:30 p.m. Modern Techniques to Engage Students Using Microcontroller Hardware and Python

Poster – Shawn Zaleski, RWTH Aachen University, Germany

Kerstin Hoepfner, RWTH University

Engaging students in a physics lab setting can be challenging. To engage students more effectively, RWTH Aachen university is replacing the first of it's advanced physics lab experiments with modern, inexpensive, and versatile devices such as Arduinos and Raspberry Pis. This represents a transition from more familiar, larger setups that find limited uses to a modular, lighter weight format. The Arduino reads voltages differences output from various devices, translated into e.g. temperature, Geiger-Mueller data, current, etc. communicated via Python code to Raspberry Pi, or bluetooth to student smartphones. This allows students to work with modern data collection methods and engage the experiment in a format more familiar to them. A significant advantage is that the instructor can easily tailor the experimental setup to a broad range of students. We present two use cases where the Arduino is connected by either a Raspberry Pi or bluetooth + smartphone combination.

PS-B.01: 12:30-1:30 p.m. Pacemaker Circuit Simulator – A New RC Circuits Lab

Poster – Diego Valente, University of Connecticut

James Jaconetta, University of Connecticut

As part of our efforts to pivot our calculus-based introductory physics sequences toward a studio-based instructional model, we sought to modernize several of the traditional lab experiments administered in these courses. One of the most traditional lab experiments in a second-semester introductory physics course covering E&M involves a study of RC circuits, though historically students tend to struggle with the abstract theoretical nature of this experiment. With the introduction of breadboards and oscilloscopes in our instruction of fundamental circuits, we have redesigned our RC circuits lab to incorporate a circuit model that simulates the behavior of a pacemaker, presenting the details of implementation in this work. This more applied approach to a traditional experiment presents greater relevance to engineering students, particularly those on a biomedical or electrical engineering track, though this experiment can also be adapted to students on a pre-med track.

PS-B.01: 12:30-1:30 p.m. Smart Phone Applied in Measurement Refractive Index

Poster – Shihong Ma, Fudan University, Shanghai, China

Youjia JIN, Department of Physics, Fudan University

The ambient light sensor on mobile phone was used as a luxmeter to measure the intensity of reflection light in the Brewster angle experiment?The refractive index of prism was determined by fitting the experimental curve of reflection coefficient and incident angle with Fresnel's equation?Systematic error analysis including incident angle, polarizer, and ambient light sensor and their consequences were discussed.

PS-B.01: 12:30-1:30 p.m. The Effect of Mousebites on Energy Resolution in the CMS HGCAL

Poster – Rhea Khatri, University of Maryland, College Park, MD 20740

Kate Sturge, University of Maryland

We quantify how mousebites–truncated tips of sensors–in the Compact Muon Solenoid (CMS) detector endcap calorimeter upgrade, the High-Granularity Calorimeter (HGCAL), affect energy resolution. Using 400 generated electrons and positrons for various energy values (20, 30, 50, 70, 100, 150, 250, 500, 1000 GeV), we summed the reconstructed hits for each energy value for both mousebites on and off, looking at the standard deviation of the energy for each fit. We then plot the energy resolution as a function of energy and fit a function to the curve. The parameters for this fit show little degradation in the energy resolution measurements between mousebites on and mousebites off, as the calculated percent difference in sampling terms is 3.5%

PS-B.01: 12:30-1:30 p.m. Using 3D Printed Atomic Force Microscope Models to Facilitate Instruction

Poster Merrell A. Johnson, Purdue University, Fort Wayne

Three low cost, raspberry pi controlled atomic force microscope models will be presented. Two of the systems are more compact, which utilize inexpensive servo motors and either laser cut or 3D printed components to build the two dimensional scanners. The third larger system uses 3D printed parts, a series of stepper motors and belt drives to create a scalable scanner. A series of investigations that were created as precursors to operating the instruments will be presented. The goal of these experiments is to help students understand concepts pertaining to the resonance of cantilevers and how those ideas are employed in measuring forces. A presentation on how the knowledge relevant to measuring forces with cantilevers and the two dimensional stages are used to map a metallic surface with a magnetic probe. A discussion on how these systems were employed for instruction in the classroom will also be exhibited.

Labs/Apparatus III

PS-B.01b: 12:30-1:30 p.m. How Can You Light The Bulb? – Student Engineered Electrophorus

Poster – Bree Barnett Dreyfuss, Amador Valley High School, 2 Pleasanton, CA 94566

Students are tasked with lighting a small neon bulb with small amounts of electric charge using an electrophorus they built. An electrophorus device is often used to demonstrate electric charging by induction. The basic structure of the device (a handle made of a cup attached to a plate) and the mechanism to charge the electrophorus is demonstrated to the students but the materials of each part are not revealed. Student groups are given four cups and four plates, one each made of aluminum, paper, plastic and styrofoam. Each group tries different combinations of the cup and plate materials until they get the neon bulb to light. The next stage is to try to improve their device and correctly explain how the bulb can be made to light up. Sample student guides, lesson logistics and suggestions for different grade levels will be discussed.

PS-B.01b: 12:30-1:30 p.m. How to Do an Advanced Lab Course at Home, on Short Notice

Poster – Eric Black, Caltech MC, Pasadena, CA 91125

The transition to remote learning in March of 2020 came suddenly and with little warning. Fortunately, the closure of campus happened during finals week of Winter Term for those of us on the quarter system, so I had a full week during spring break to develop and deploy a curriculum that our students could do from home during Spring Term. Starting with John Essick's excellent textbook on LabVIEW and continuing with having hardware drop shipped from National Instruments to the students' home addresses, we were able to cover quite a bit of material, almost all of the projects worked, and at the end of the term many students commented that they genuinely enjoyed the course.

PS-B.01b: 12:30-1:30 p.m. Student-Centered Approach to Online Radiation Experiments During a Pandemic

Poster –Yugjeet Grewal, California State University, Fresno

Raul Reynoso, Ruben Reyes, Javier Santos, John Walkup, California State University, Fresno

First-year students at California State University, Fresno learn to perform scientific research through a Building Opportunities with Networks of Discovery (BOND) course sequence. Students perform their own research as a culminating project. Although COVID-19 eliminated on-campus student involvement, one group of freshmen was undeterred. Spurred by a presentation on the dangers of radium, they decided to complete their research nevertheless. Using a Geiger-Muller tube and sound-capturing software, they measured to reasonable precision the half-layer of steel in absorbing high-energy gamma rays emanating from a Revigator, an early quack medical device. The poster describes how they conducted radiation exposure experiments through Zoom, with the instructor acting in the reversed role of "Lab Rat," and how their procedure can drive similar online radiation experiments without compromising student safety. Finally, it describes how such a project offers lessons in medical history, especially disasters that unfolded when greed and ignorance supplanted science.

PS-B.01b: 12:30-1:30 p.m. The iPad as a Virtual Oscilloscope for Measuring Time Constants in RC and LR Circuits*

Poster – Roberto Ramos, University of the Sciences, Philadelphia, PA 19104

In a university introductory physics laboratory, the measurement of time constants in RC and LR circuits usually employ a conventional oscilloscope. The standard oscilloscope with its many knobs and switches often intimidate first-time users and can cause anxiety especially among non-physics and non-engineering majors. On the other hand, an iPad has a more familiar, less intimidating and friendlier touch-pad interface. We report our experience in using the iPad as a virtual oscilloscope in an introductory algebra-based physics laboratory course. We used a commercial electronic accessory called Oscium iMSO that turns the iPad into a virtual oscilloscope. Using blind surveys and direct observation, we report student responses to this pedagogical tool.

*Based on Publication: Phys. Educ. 55 (2020) 023003

PS-B.01b: 12:30-1:30 p.m. Treatment of Statistics and Error in Introductory Physics Lab Manuals

Poster – Jimmy Gonzalez, University of California, Merced Merced, CA 95343

John R. Walkup, California State University, Fresno

Many students experience their first practical application of statistics and error analysis conducting activities in their introductory physics labs. During this time, they learn definitions, concepts, and skills they will use for the rest of their academic and postgraduate career. The authors will present their analysis of the use of statistical methods used in labs by comparing lab manuals aimed at science and engineering students collected from two-year community colleges and four-year universities. Approaches to introducing statistical concepts and procedures are examined for consistency, with reference to national and international guidelines such as the NIST and ISO. Their analysis reveals severe inconsistencies in the treatment of statistics and error among the samples. Most notably, wide disparities surfaced in terminology and relationships, along with a dearth of topics that should have warranted a more concerted treatment. Results point to potential inadequate development of statistical reasoning skills among future scientists and engineers.

PS-B.01b: 12:30-1:30 p.m. Using Spoons as Spherical Mirrors

Poster – James L. Hicks, Northeastern State University, Tahlequah, OK 74464

An "at-home" version of an introductory physics 2 lab involving spherical mirrors is proposed. In the regular, face-to-face laboratory experiment, students measure the focal length of commerically available spherical mirrors, both concave and convex, using an optical rail. Most students will not have easy access to these types of mirrors at home but a reasonable replacement can be found using the front and back surface of a metal spoon. This provides both a concave mirror and convex mirror with very similar focal lengths. Students were given the task of determing the focal length of the spoon in addition to several general suggestions for measurement techniques. Several of the students' techniques will be discussed along with their accuracy and possible improvements for implementing this "at-home" lab.

WEDNESDAY

Astronomy Poster

PS-B.02: 12:30-1:30 p.m. A van der Waals Phase Transition in a Compact Star

Poster – Keith Andrew, Western Kentucky University, Bowling Green, KY 42101

Kristopher A. Andrew, Lexington Montessori High School

David Suarez, Cody J. Humphrey, Gatton Academy/Physics and Astronomy WKU

Many students are familiar with the ideal gas law equation of state which is often treated in early chemistry courses. They are also familiar with phase transitions and phase diagrams but have not explored phase transitions with a quantitative model or the units used in physics and astrophysics applications. Here we look at an application of the van der Waals equation of state to a planetary interior and to the quark-hadron phase change in a compact stellar core using Newtonian gravity. Students used the quark phase diagram with data from accelerator experiments to estimate the van der Waals constants to construct an equation of state. The resulting equation includes the modeled phase transition with binodal and spinodal curves describing a superheated liquid state and a supercooled vapor state. Students visualized the results in Mathematica and were surprised to see core stellar temperatures near a trillion Kelvins.

PS-B.02: 12:30-1:30 p.m. Combining Existing Technology & Resources for Stronger Outreach In Today's World

Poster – Dave G. Milewski, University of California Los Angeles, Department of Earth, Planetary, and Space Sciences

Emmanuel V. Masongsong, University of California Los Angeles

The 1969 Apollo 11 Moon landing led to significant advances in technology while heightening enthusiasm for science, creating a lasting impact. Half a century later, people are still mesmerized by the wealth of continued returns in many fields, with unprecedented levels of interest in astronomy and space exploration. Now in its 11th year, NASA's International Observe The Moon Night Event proves how simple community strategizing leads to widespread education and outreach to citizens of all ages. Combining numerous scientific demonstrations (including basic physics, meteorite specimens, and historical Apollo artifacts), we make planetary science accessible for everyone. Via UCLA Institute for Planets and Exoplanets, a joint-collaboration amongst specialists in multiple UCLA departments, and people involved in NASA missions, those specialties of professional scientists are merged to bring their expertise to the public. We hope to expose everyone to basic science and scientific phenomena empowering the next generation of researchers and explorers.

PS-B.02: 12:30-1:30 p.m. Disentangling Student Understanding of Apparent Motions of Sun and Stars

Poster – Mieke De Cock, KU Leuven, Belgium

Hans Bekaert, Wim Van Dooren, An Steegen, Hans Van Winckel, KU Leuven

Understanding the apparent motion of the Sun, Moon and stars from the point of view of an observer on Earth is seen as an essential starting point for the study of many astronomical phenomena. However, research has shown that children as well as secondary school and university students and adults have difficulties with these basic concepts. In this contribution, we describe the design of the Apparent Motion of Sun and Stars test, an instrument to measure to what extent students have insight in the apparent motion of Sun and stars. We disentangled the phenomena related to these apparent motions and we propose a framework that allows comparing students' understanding of the different aspects of these motions for the Sun and the equivalent for the stars. We present the framework, the reliability and the validity of the instrument. Moreover, we report on the results of our qualitative analysis of student reasoning.

PS-B.02: 12:30-1:30 p.m. Hands-on General Relativity Activities for Introductory Astronomy

Poster – David L. Morgan, Richard Bland College, Chesterfield, VA 23834

This poster presentation will present several hands-on "lab" activities for introducing students in the astronomy classroom to some of the basic ideas of general relativity. Most of the activities involve paper & pencil measurements and simple objects like balls, balloons, flower vases and globes. Activities that explore Hubble's Law and the accelerating expansion of the universe will also be shown. Finally, a simple activity will be described that makes use of the cosmological models built-into the Wolfram Alpha computational engine.

PS-B.02: 12:30-1:30 p.m. New Information on Pulsating RR Lyrae Star DM*

Poster – Adanna Frazier, Lee College, Baytown, TX 77521

Thomas L O'Kuma, Lee College

This is a study of the photometric data of the RR Lyrae star, DM And, in the B, V, sdss-i, and sdss-z filters. The light curve shapes and estimated period (.63115 days in the B-filter, .6294 days in the V-filter, .632 days in the sdss-i filter, .63225 days in the sdss-z filter, and an average period of .6312 days) represent that of a typical RRab type RR Lyrae star. However, not everything measured correlated with expected results.While qualitative spectroscopic parallax in B and the measured distance using V-Band period luminosity relationship agree with GAIA, the sdss-i and sdss-z filters did not due to the star showing significantly dimmer magnitude (a magnitude difference of .144 in the sdss-i filter and .76 in the sdss-z filter, compared to the RR Lyrae star AF Vel). There is also significant variations in the measured distances which resulted in an inconsistent average distance of 1,924.8 parsec.

*This is an undergraduate research project through the Our Solar Siblings Pipeline using data from robotic telescopes. Sponsored by Tom O'Kuma.

PS-B.02: 12:30-1:30 p.m. Nucleosynthesis for High School Students

Poster – Margaret A. Norris, Black Hills State University / Sanford, SD 57754

The synthesis of new elements in cosmic events - on both slow (fusion in stars) and fast (supernovae, colliding neutron stars) time scales - is an unsettled science topic that excites the imagination. When the LIGO/VIRGO collaborations observed the first gravitational waves from colliding neutron stars in 2017, nuclear astrophysics and gravitational physics combined to generate the new field of MultiMessenger Astronomy (MMA). MMA connects to classrooms through both physical science standards (nuclear processes, energy) and earth/space science standards (Earth's Place in the Universe). We have developed an activity to model nucleosynthesis in the classroom by having students explore the competition between slow-neutron capture (the s-process) and rapid-neutron capture (the r-process) at different sites in the cosmos. The activity introduces modeling, probability and nuclear beta-decay. It can be used as a culmination of a unit on the origin of the elements or as a stand-alone activity.

PS-B.02: 12:30-1:30 p.m. Reacting to the Present: A Role-Playing Game for Introductory Astronomy

Poster – Josh Fuchs, Texas Lutheran University, Seguin, TX 78155-9996

Margaret Gonzales, Texas Lutheran University

The Astronomy Decadal Survey occurs once every ten years to determine priorities for the next decade in astronomy. We describe a new role-playing game designed for Introductory Astronomy courses in which students play the roles of current astronomers to decide which projects should be funded. Students must use knowledge gained from the whole class to decide how to balance scientific priorities and feasibility, funding levels, cultural sensitivities, and global cooperation to rank six telescope proposals. This game engages students in the course material by having them debate each other and provides a summative activity to assess learning outcomes. We will describe how the game is structured and implemented, learning outcomes, and make it freely available.

PS-B.02: 12:30-1:30 p.m. Student Perceptions of Observation

Poster – Jacqueline M. Dunn, Midwestern State University, Wichita Falls, TX 76308

When teaching astronomy, we present many concepts and facts learned via observation alone. One problem encountered in astronomy is convincing students that astronomers know what they say they know about an object. Beyond teaching students what we can learn from light, and how we can learn from observations of light, we need to teach students that we can learn from observation alone. To gauge student beliefs about the utility of observation, an exercise was designed where students would observe people without interacting them in any way. The goal was for students to see what they could learn just through observation. A comparison was made between student attitude's across two groups: non-science majors and science majors. Surprisingly, the science majors showed a lack of appreciation for the utility of observation alone, while the non-science majors were surprised by the conclusions they were able to form through their observations.

PS-B.02: 12:30-1:30 p.m. The Pan-African School for Emerging Astronomers

Poster – Linda E. Strubbe, American Association of Physics Teachers

The Pan-African School for Emerging Astronomers (PASEA) is a short course in astronomy for university students from across Africa, designed and taught by a collaboration of astronomers from Africa and around the world. Our program started in West Africa in 2013, where it was known as WAISSYA, and has been held four times in Nigeria and Ghana. Building on our success and the enthusiasm of African participants outside West Africa, our team decided to expand to a Pan-African program. Our goals include building a critical mass of astronomers across Africa, and exchanging teaching ideas between Africa and outside. I highlight four major aspects of PASEA and their significance to Astronomy for Development across Africa: (1) our inquiry-based curriculum; (2) "paired-teaching," in which international partners teach together to exchange and learn new ways of teaching; (3) our active alumni community; and (4) our evaluations to measure the effectiveness of the program.

PS-B.02: 12:30-1:30 p.m. Working with Real Astronomy Data

Poster – Luisa M. Rebull, Caltech-IPAC, Pasadena, CA 91125-0001

Did you know there is a lot of professional astronomy data out there, right now, available to you, for free? Professional astronomy archives are open to the public; tools are getting better all the time to not just access these data, but also work with them. This poster summarizes how to access data from IRSA, the Infrared Science Archive (http://irsa.ipac.caltech.edu). The online tools give you access to multi-wavelength data (images and catalogs) and provide basic tools for analysis.

Lecture/Classroom III

PS-B.05: 12:30-1:30 p.m. A Motor-Driven Generator with a Gearbox Is Not a Perpetual Motion Machine

Poster – Douglas S. Goodman, Quinnipiac University, Hamden, CT 06518-1908

James E Wells College of the Sequoias

Perpetual motion machines capture the imagination of many students and instructors. We know that perpetual motion is impossible, nevertheless the explanation for why specific designs fail is not always obvious and is often interesting. One of our students proposed a perpetual motion machine that uses a dc electric motor to drive a dc electric generator through a gearbox. The gearbox rotates the generator multiple times per motor revolution, generating a larger emf across the generator than the motor. We discuss how the energy is partitioned between the motor and the generator as a function of gear ratio, assuming a frictionless gearbox. Alas, our analysis debunks our student's proposed perpetual motion machine. However, in doing so, we find conditions for two critical gear ratios, one that maximizes the time-averaged generator power output and another that optimizes the time-averaged energy conversion efficiency to 40%.

PS-B.05: 12:30-1:30 p.m. Exploratory Factor Analysis of the QMCA

Poster – Adam T. Quaal, California State University, Fullerton

Gina Passante, California State University, Fullerton

Steven J. Pollock, University of Colorado, Boulder

Homeyra R. Sadaghiani, California State Polytechnic University, Pomona

This investigation is situated within a larger, ongoing project which seeks to understand student thinking in upper-division introductory quantum mechanics courses. We use the Quantum Mechanics Concept Assessment (QMCA) to explore the distinction between student thinking on multiple-choice questions in position-basis and spin-basis contexts. In this work, we utilize the technique of exploratory factor analysis to group items on the QMCA based on their common variance. In interpreting the resulting factor structure, we focus on the placement of isomorphic questions and the original concept framework of the QMCA. We discuss the implications of our findings to subsequent iterations of the QMCA and the future study of student thinking in these two contexts.

PS-B.05: 112:30-1:30 p.m. Maxwell and Sutton: A Mystery Connecting Science, Art and Technology

Poster – Frederick J. Thomas, Learning with Math Machines, Inc., Freeland, MI 48623-8671

James Clerk Maxwell is properly recognized for his important theoretical work on electromagnetism. His collaboration with Thomas Sutton to produce the first permanent color photograph is less well-known, despite having initiated the RGB technologies we continue to use. This intersection of physics, human physiology, chemistry, art and technology can be an attention-grabbing lecture example, or it can be an in-depth student research project that utilizes Sutton's extensive and recently reprinted writings. In addition, the Maxwell-Sutton photograph presents an authentic, ongoing mystery: Could photographic plates from 1861 that were not sensitive to red light have actually yielded a red component for Maxwell to display during his lecture?

PS-B.05: 12:30-1:30 p.m. Particle Interactions Simplified with a Tripreon Model for Students*

Poster – Peter J. Riley, Deakin University, Geelong, VIC 3216 Australia

Whatever other virtues may exist for preon models of elementary particles, there are pedagogical benefits in simplifying vertex interactions for junior HEP students. The Tripreon model is a more intuitive method of tracking Quantum Numbers. A Standard Model example, neutron decay: n0 -> p+ + e- + Ve, which resolves to a quark decay (udd) -> (uud) with the vertices d.W+ -> u and d -> u.W- (uppercase antimatter). How exactly does that happen? Well, we can keep a tally of numerous QNs to ensure all are conserved and verify with past instances. But, what exactly happened? If the QNs are carried by three types of preons (a,b,d) then the d.W+ ->u vertex may be visualised (b.BD).(a.B) -> (a.BD) respectively. Note that the same number of particle types exit the vertex as enter the vertex where b. and .B annihilate. An overview is presented with examples and suggested activities.

*Preon Trinity - A Schematic Model of Leptons, Quarks and Heavy Vector Bosons, Jean-Jacques Dugne, Sverker Fredriksson and Johan Hansson, Euro.Phys.Letters, (Aug 2002).

PS-B.05: 12:30-1:30 p.m. Particle Physics Research within UMD's FIRE Program

Poster – Muge Karagoz, University of Maryland

The University of Maryland's First-Year Innovation & Research Experience (FIRE) is a 3-semester gen-ed program with a first-semester enrollment of more than 600 undergraduates. FIRE provides faculty-mentored research experience and career-readiness with more than 15 diverse research streams available to its students in their second and third semesters. In 2019, I launched a FIRE stream called "Simulating Particle Detection" (SPD), to introduce undergraduate students to the field of experimental high energy particle physics. The research concentrates on computing and data analysis using simulations of novel detectors, specifically, the upgrade calorimeters of the CMS experiment at CERN. While high energy physics experiments are at the forefront of large collaborative research, large-size, university-wide, course-based research experiences are not as common. There are challenges to be addressed to serve about thirty undergraduates every year, such as adaptation of a high-level research topic into a course curriculum, physical and digital research setting logistics, and mentoring of students from different disciplines. I will share my experiences from the first-year running of SPD, highlighting not only research but also pedagogical methods and outcomes concerning the above challenges.

PS-B.05: 12:30-1:30 p.m. Representing Torque with Oriented Parallelograms

Poster – Brian Frank, Middle Tennessee State University, Murfreesboro, TN 37130

In introductory algebra-based physics courses, I have been teaching static equilibrium problems using an oriented area representation of torque. In this poster, I will provide examples that illustrate the approach as applied to a variety of contexts and discuss aspects of classroom implementation.

PS-B.05: 12:30-1:30 p.m. Sketch Production Rules Before Designing, Categorizing, Solving, and Grading Problems

Poster – David Liao, Bedminster, NJ 07921

This poster is a printable guide sheet for using a network representation of production rules when (a) designing problems with intentional amounts of emphasis on different thinking tasks (e.g. focus more on governing relationships or constitutive relationships? focus more on straightforward processing of situations or tricky ontological shifts?), (b) categorizing problems according to types of difficulty, and (c) showing students how to select first principles to solve problems.

PS-B.05: 12:30-1:30 p.m. Using Quantum Dots to Teach Introductory QM Concepts and Applications

Poster – Jonathan Bennett, NCSSM, Durham, NC 27705

We purchased CdSe quantum dots (QDs) of different sizes from a science supply company and used a transmission electron microscope (TEM) to image them. Students can easily examine fluorescence spectra and TEM images of these quantum dots and can use the "particle in a box" model to describe the relationship between radius of QD and emission wavelength. Using the widths of emission lines and Heisenberg's energy-time uncertainty principle, students can estimate the lifetimes of the excited states of the QDs. We will share some of the results obtained by students. Instructors who are interested in using the TEM images and/or fluorescence spectra may get them by contacting the author.

PS-B.05: 12:30-1:30 p.m. Working for a Better World: Astronomical Observatories and their People*

Poster – Carmen A. Pantoja, University of Puerto Rico

Mayra E. Lebrón, University of Puerto Rico, Río Piedras

In this poster we describe the creation and display of a traveling image exhibit about astronomical observatories. The visitors can learn about science at different observatories as they stroll through the electromagnetic spectrum. The exhibit includes: facts about the observatory, an example of the science studied at the observatory, a description of how light is detected, and highlights the people that make the discoveries possible. A special effort has been made by means of concrete materials and demonstrations to promote the active participation of diverse audiences (students, teachers, college professors, general public, amateur astronomers, and the visually impaired). This traveling exhibit allows people from different regions in Puerto Rico to learn about new discoveries, technologies and careers in science. *This project is funded by an American Physical Society Public Outreach and Informing the Public Mini Grant.

Physics Education Research VI

PS-B.06: 12:30-1:30 p.m. A Critical Examination of DFW Rates in LA Supported Physics Courses

Poster – Ben Van Dusen, CSU Chico, Chico, CA 95928

Jayson Nissen, J.M. Nissen Consulting

The American Physical Society calls for improving the diversity of physics by supporting an inclusive culture that encourages women and people of color to become physicists. Evidence shows that a major barrier to pursuing a career in physics or any other STEM discipline is passing the introductory physics course. We investigated the intersectional nature of racism, sexism, and classism in inequities in student rates of earning a non-passing grade (d, f, or withdrawal; DFW) using a quantitative critical framework. The analyses examined DFW rates for students in LA and non-LA supported physics courses at a Hispanic Serving Institution. Results identified large differences across intersecting identities. Controlling for instructors, LAs were found to be associated with decreases in DFW rates across all demographic groups.

PS-B.06: 12:30-1:30 p.m. A Metric for Comparing Populations Using Item Response Curves

Poster – Paul J. Walter, St. Edward's University, Austin, TX 78704-6489

Ed Nuhfer, California State University (retired)

Crisel Suarez, Vanderbilt University

We introduce a valuable metric for comparing any two populations on a multiple-choice test instrument. Our case example uses real data from 12,803 participants on the validated 25-item Science Literacy Concept Inventory (SLCI) and a simulated dataset of all of these participants randomly guessing. The metric employs a weighted dot product of two normalized N-dimensional vectors where N is the number of possible overall scores (i.e., 26 for item scores ranging from 0 – 25). The percentages of students that select each particular answer choice on a multiple-choice test instrument provide the components of the vectors. The value of each dot product of vectors is a single number between 0 – 1, for each test item for each unique pair of populations. The single numbers enable easy comparisons of paired populations, such as binary genders. The number differences quickly identify those items which merit further investigation for explaining the differences. With sufficiently large populations, the item response curves of paired populations proved much closer to each other than did the item response curves between real participants and the simulated population of the same size that was randomly guessing.

PS-B.06: 12:30-1:30 p.m. Assessment of Knowledge Integration in Learning Physics*

Poster – Lei Bao, The Ohio State University, Columbus, OH 43210-1117

Joseph Fritchman, The Ohio State University

Kathleen Koenig, University of Cincinnati

Student development of deep understanding of core scientific ideas and cross-cutting concepts in STEM disciplines is the focus of current framework for science education. Research has shown that deep learning can be achieved through knowledge integration where fragmented connections between and within concepts are strengthened through experience within differing contexts. However, few studies point towards specific methods for assessing and supporting knowledge integration in the classroom. This presentation will introduce Conceptual Framework, which has been shown to be promising as an operational approach for modeling assessment and instruction that target knowledge integration. A conceptual framework maps the possible knowledge structures of novice and expert students and help identify missing connections between conceptual core ideas and other elements within the knowledge structure. Examples and current studies using the conceptual framework approach will be discussed.

*Supported in part by the NSF IUSE-1431908 and IUSE-1712238

PS-B.06: 12:30-1:30 p.m. Evaluating Context-Oriented Teaching Materials for Electricity Lessons

Poster – Liza Dopatka, TU Darmstadt, Germany I*

Verena Spatz, TU Darmstadt

In the past decades, physics education research has repeatedly shown that German students' interest in physics is often low. This is particularly worrying as students' interest is an important factor for the learning process. Therefore, a lot of projects have focused on promoting students´ interest in physics classrooms. Our approach is to design und evaluate context-oriented teaching material. There are some well-established research scales available to assess students' interest in physics that - so far - have largely been used unrelated to each other. Against this background we have decided to integrate two of these common constructs in a questionnaire for our current study to assess high school students' interest in context-oriented physics lessons about electricity (N = 1629). On the poster we will present our ideas for the design of context-oriented teaching material in electricity and the newly structured interest scales.

*Sponsored by Cyrill Slezak

PS-B.06: 12:30-1:30 p.m. Extending Modified Module Analysis to Include Correct Conceptual Physics Responses

Poster – John C. Stewart, West Virginia University, Morgantown, WV 26506

James Wells, College of the Sequoias

Rachel Henderson, Michigan State University

Brewe, Bruun, and Bearden first applied network analysis to understand patterns of incorrect conceptual physics reasoning in multiple-choice instruments introducing the Module Analysis for Multiple-Choice Responses (MAMCR) algorithm. Wells et al. proposed an extension to the algorithm which allowed the analysis of large datasets called Modified Module Analysis (MMA). This method analyzed the network structure of the correlation matrix of the responses to a multiple-choice instrument. Both MAMCR and MMA could only be applied to networks of incorrect responses. This poster presents an extension of MMA which allows the analysis of networks involving both correct and incorrect responses. The new algorithm was applied to the FCI and recovered much of the structure identified by MMA, identified sets of correct answers requiring similar physical reasoning, and identified some groups of responses which mixed correct and incorrect responses.

PS-B.06: 12:30-1:30 p.m. Multidimensional Item Response Theory and the BEMA

Poster – John Hansen, West Virginia University, Morgantown, WV 26506

John Stewart, West Virginia University

The Brief Electricity and Magnetism Assessment (BEMA) is a 31-question assessment designed to assess student understanding of basic principles of electricity and magnetism in an introductory, calculus-based physics course. This study develops a model of student knowledge measured by the BEMA. This is guided by a theoretical model of expert understanding of electricity and magnetism. Multidimensional Item Response Theory (MIRT) was used to investigate a large post-test dataset (N=9666) from a large, western public research university collected over the span of 15 years. An optimal model was found by exploring variations to the theoretical expert model and selecting the model with the optimal MIRT fit parameters.

PS-B.06: 12:30-1:30 p.m. Network Analysis of the CSEM with Modified Module Analysis

Poster – Christopher Matthew Wheatley, West Virginia University, Morgantown, WV 26506

Jie Yang, John Stewart, West Virginia University

This research applied Modified Module Analysis (MMA) to over 5000 student responses to the Conceptual Survey of Electricity and Magnetism (CSEM). The CSEM was given at two major US land-grant universities in the introductory Electricity and Magnetism courses. MMA is a powerful tool for analyzing large datasets that uses the correlation matrix to form a network, community detection algorithms, and bootstrapping. Many studies have investigated student misconceptions in Newtonian physics by analyzing instruments such as the Force Concept Inventory or the Force and Motion Conceptual Evaluation. These studies showed that students hold non-Newtonian views on classical mechanics even post-instruction. However, much less research has investigated misconceptions in E&M. This study identifies communities of correct and incorrect answers to the CSEM to explore the structure of student misconceptions.

PS-B.06: 12:30-1:30 p.m. Role Analysis of Student Networks in Active Learning Physics Classes

Poster – Adrienne L. Traxler, Dayton, OH 45435-0001

Tyme Suda, Wright State University

Eric Brewe, Kelley Commeford, Drexel University

The Characterizing Active Learning Environments in Physics (CALEP) project combines classroom observations with network analysis to identify distinctive features of research-based physics curricula. This poster compares the social positions available in student networks from four classes, looking for major similarities or differences across learning environments. Role analysis looks for common structural patterns in a network. It groups people who have a similar pattern of connections, whether or not they know each other. We find that coherent subgroups are the most common structure in the late-semester networks of the sections analyzed. This differs from many networks in sociology studies, where other patterns such as hierarchy are more common. Comparing these courses, the social positions are more alike to each other than different. A wider sampling of data would be needed to claim that this is a "typical" active learning network signature, and would also provide a baseline for studying network-building interventions.

PS-B.06: 112:30-1:30 p.m. Using Group Exams to Address Persistent Intuitively Appealing but Incorrect Student Reasoning*

Poster – Alistair G. McInerny, North Dakota State University, Fargo, ND 58105

Mila Kryjevskaia, North Dakota State University

Many students tend to provide intuitively appealing (but incorrect) responses to some physics questions despite demonstrating (on similar questions) the formal knowledge necessary to reason correctly. While these inconsistencies are typically persistent even in active learning environments, we believe that adding a group component to the exam may engage students sufficiently to resolve these instances of inconsistent reasoning. In our study, students were given opportunities to revisit their answers to questions known to elicit strong intuitively appealing (but incorrect) responses in a collaborative group component of an exam immediately following a traditional individual component. Students discussed their responses with group members but were required to submit their own answers and reasoning. On this poster, we examine the effectiveness of a collaborative group exam approach in addressing and resolving inconsistencies in student reasoning and will compare the effectiveness of this approach to a more traditional peer instruction technique.

*This material is based upon work supported by the National Science Foundation under Grants Nos. DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, DUE-1821561, DUE-1431940, DUE-1431541, DUE-1431857, DUE-1432052, and DUE-1432765.

PS-B.06: 12:30-1:30 p.m. Using Machine Learning to Understand Changes in CLASS Scores

Poster – Paul M. Miller, West Virginia University, Morgantown, WV 26506-6315

Elaine Christman, John Stewart, West Virginia University

Nearly ten years ago, we began to collect pre- and post-instruction data about content and attitudes from every student enrolled in both semesters of calculus-based introductory physics. While the content results from the FMCE and CSEM instruments have been explored in several ways by the WVU PER group, the attitudes data using the Colorado Learning Attitudes about Science Survey (CLASS) have gone relatively unexplored. In this poster, I will present the results of an exploration of this large (N > 3000) data set from a large eastern land- grant university serving approximately 30,000 students. We first summarize the data set in the traditional way, as a shift from pre to post in favorable vs. unfavorable or expert-like vs. novice answers. We, then, examine and report to what degree other variables in our data set can predict this shift among the population using machine learning algorithms.

Physics Education Research VII

PS-B.07: 12:30-1:30 p.m. Evaluation of Student Understanding of the Hand Rules in Electromagnetism

Poster – Yikun Han, The Ohio State University, Columbus, OH 43210

Lei Bao, The Ohio State University

Feipeng Pi, Guangzhou University

In the Chinese high school physics curriculum, the Ampere's rule, the left-hand rule, and the right-hand rule are used to determine the direction of the magnetic field, the ampere and Lorentz force, and the direction of the electric current.Actually at different phases,students confused that which rule is more suitable,it causes inefficiency when they deal with problems.The central idea of these three rules is the cross product, teachers help students to build the concept of cross product,meanwhile training deep learning of electromagnetism knowledge.Therefore, through an assessment tool to understand the mastery of these three rules at different phases of their learning.

PS-B.07: 12:30-1:30 p.m. Factors Associated with Students Graduating in STEM at a Military Academy

Poster – Jessica Dwyer, Center for Physics Education Research, Department of Physics, USAF Academy, CO 80840-6254

Wilson Gonzalez-Espada, Physics, Earth Science & Space Systems Engineering Dept., Morehead State University

Kimberly de La Harpe, David Meier, Center for Physics Education Research, Department of Physics, USAF Academy

The U.S. is not graduating enough science, technology, engineering and mathematics (STEM) majors for the increasing number of available employment opportunities and national security needs. The purpose of this study was to quantify the magnitude of STEM attrition at the U.S. Air Force Academy (USAFA). The study also identified factors associated with STEM attrition among students. Despite strong academic preparation, of the students who reported their intention to major in a STEM discipline as incoming freshmen, 36.4% switched and graduated with a non-STEM degree. The best predictors associated with students graduating with a STEM major were their initial intention and motivation to major in these disciplines upon arrival at USAFA and course grades in Calculus I, Calculus-based General Physics I and Applications of Chemistry I. These findings suggest that students motivated to major in STEM may switch out if they struggle with prerequisite quantitative courses.

PS-B.07: 12:30-1:30 p.m. Student Conceptual Resources for Understanding Kinematics*

Poster – Cheyenne M. Broadfoot, University of Washington

Brynna H Hansen Seattle Pacific University

Amy D Robertson Seattle Pacific University

Physics education research on student understanding of kinematics has largely focused on misconceptions and difficulties. Our project reports student resources for understanding kinematics — ideas that we consider to be the “beginnings” of sophisticated understandings. Our preliminary analysis highlighted four common resources that students are using to solve kinematics problems. In this poster, we will elaborate on the resources used most often by students and give examples from our preliminary research.

*This work is supported in part by NSF grant numbers 1914603 and 1914572

PS-B.07: 12:30 PM-01:30 PM Students’ Reasoning During Qualitative Physics Problem Solving

Poster – Bashirah Ibrahim, Bahrain Teachers College, University of Bahrain

Lin Ding, The Ohio State University, School of Teaching and Learning

Reasoning is a predictor of learning and is a key skill needed for science. In physics, there is a lack of studies exploring how students reason with particular concepts when handling qualitative, conceptual physics questions. Our work is based on Kuhn’s (2004) framework which defines scientific reasoning as the conscious intent to seek new information to enhance knowledge and understanding. The core of Kuhn’s framework is theory-evidence coordination, and it emphasizes the importance of cognition for scientific reasoning. Fifty freshmen, with a calculus-based physics background, completed three open-ended qualitative physics questions. The problems, borrowed from published instruments, dealt with the energy conservation principle. Data from the students’ written and interview responses show (i) the students’ source of self-generated evidence, and (ii) their meta-cognition in answering the qualitative physics questions.

PS-B.07: 12:30-1:30 p.m. Teaching Geometric Optics Through Drawing Ray Diagrams

Poster – Yue Xiao, Columbus, OH 43202

JianWen Xiong

Lei Bao

Drawing ray diagram is the kay strategy to solve optics problems. Through interviewing junior high school students in China, they reflect that they mostly memorize the final results of special cases to solve the problems in homework and exams, even problems about lens requesting drawing are also solved by memorizing special rays. It appears that the drawing ray diagrams is not emphasized in instruction, which leads to students’ inability to make connections between principles of geometric optics and the final outcomes that they memorized. In order to promote deep learning, a conceptual framework on geometric optics is introduced to map out students’ knowledge structures. Based on the conceptual framework, an assessment test is developed to evaluate students’ conceptual understanding of geometric optics. Results of the assessment will be discussed to emphasize the ray diagram is the new method to teach geometric optics.

PS-B.07: 12:30-1:30 p.m. The Long-Term Effects of Learning Physics Through ISLE

Poster – Danielle Bugge, Rutgers University, New Brunswick, NJ 08901

Eugenia Etkina, Rutgers University

Today’s high school students need to develop abilities and skills that are applicable across many fields. Recommendations from the NGSS call for integrating science practices into learning of normative concepts in science classrooms. In my classroom, students learn physics through the Investigative Science Learning Environment (ISLE) approach. Based on previous studies, we know that ISLE students are capable of developing science-process abilities. However, how do we know if this approach to curriculum design and learning prepares students for success in the future? I administered a survey to alumni who learned physics through the ISLE approach and followed up the survey with interviews and a focus group. I report on the findings from this study with regard to what students remember learning, how their mindset changed during their time in the course, and what elements of their experience had an effect on and/or were transferrable to their future courses and careers.

PS-B.07: 12:30-1:30 p.m. Ups and Downs of ISLE-based Reforms in an Urban Public University

Poster – Diane C. Jammula, Rutgers University-Newark

Sheehan H, Ahmed, Rutgers University-Newark

Joshua Rutberg, Eugenia Etkina, Rutgers University Graduate School of Education

Research indicates that both students and instructors struggle when a course switches to implementing student-centered inquiry-oriented pedagogical approaches which engage students in construction of their own knowledge through experimentation and reasoning. One such approach is the ISLE approach that puts the students in the driver's seat of learning. Instead of reading a book and working on problems the students working in groups engage in the activities that mirror the activities of physicists constructing and applying knowledge. In large room meetings they work on activities helping them invent new ideas and in labs they design their own experiments to test and apply those ideas. How do the students and the instructors respond to innovations? This poster will present data collected during one year of ISLE-based reforms at Rutgers, Newark, an urban public university. We will share our achievements and struggles.

PS-B.07: 12:30-1:30 p.m. Using the Popular "Shoot the Monkey" Demo to Teach Problem Solving*

Poster – Joe Ross, University of Cincinnati, Greensboro, NC 27410

Alexandru Maries, Kathleen Koenig, University of Cincinnati

Robert Teese, Michele Chabot, Rochester Institute of Technology

The "shoot the monkey" demonstration is a very popular and commonly used demonstration in projectile motion: a gun is aimed at a monkey hanging from a branch. At the instant the gun is fired, the monkey lets go, and of course, the bullet hits the monkey. Prior research has shown that demonstrations promote little learning if they are not preceded by questions related to the possible outcomes of the demonstration. We have taken this one step further by using this popular demonstration (which students often love) as the basis of an Interactive Video-Enhanced Tutorial (IVET). The "monkey-gun IVET" is designed to help students learn effective problem solving strategies by guiding them to use the physics of projectile motion to explain why the monkey gets hit. The IVET is designed based on principles of multimedia learning and is adaptive in that it provides different levels of scaffolding depending on students' needs. This presentation will showcase all the different features of this IVET.

*Work supported by the NSF IUSE Program (DUE #1821396)

Physics Education Research VIII

PS-B.08: 12:30-1:30 p.m. An Examination of Proudness in Learning Assistants (LAs)

Poster – Gregory Curry, Chicago State University, Chicago, IL 60628

Mel S Sabella, Chicago State University

Angela Little, Michigan State University

We know that moments of feeling a sense of accomplishment can affect students positively in class work and throughout their academic career. We use the idea of proudness as a way to focus in on these key moments. While proudness can take on a number of meanings we use a set of "proudness principles" to identify what makes students proud of their roles as Learning Assistants [1]. By examining Learning Assistant behavior and reflections we identify and highlight LA activities that can lead to proudness, and discuss how proudness affects their work as LAs and students. We offer suggestions on how LA Programs might support the development of proudness and identify pitfalls that can present obstacles to the development of proudness.

[1] Angie Little, "Proudness: What Is It? Why Is It Important? And How Do We Design for it in College Physics and Astronomy Education?" Status: A report on women in Astronomy, 2015 * Supported by the Department of Education, the National Science Foundation (DUE# 1524829), and the Illinois Space Grant Consortium

PS-B.08: 12:30-1:30 p.m. Exploring One Aspect of Pedagogical Content Knowledge of Physics Instructors and Teaching Assistants Using the Force Concept Inventory*

Poster – Alexandru Maries, Cincinnati, OH 45220

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.

*Work supported by the National Science Foundation

PS-B.08: 12:30-1:30 p.m. Exploring One Aspect of Pedagogical Content Knowledge of Teaching Assistants Using the Test of Understanding Graphs in Kinematics*

Poster – Alexandru Maries, Cincinnati, OH 45220

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

PS-B.08: 12:30-1:30 p.m. Identifying Student Conceptual Resources for Understanding Electric Circuits*

Poster – Jonathan Corcoran, Seattle Pacific University, Seattle, WA 98119

Lauren C. Bauman, Quest University

Amy D. Robertson, Seattle Pacific University

Most research focusing on student ideas about electric circuits frames these ideas in terms of misconceptions, difficulties, and misunderstandings. Our project reports student resources for understanding electric circuits, ideas that we consider to be the "beginnings" of foundational understanding. In this poster, we will present four conceptual resources for understanding electric circuits based on our analysis of students' written responses to conceptual circuits questions. Our aim is to add to instructors' existing knowledge of students' ideas, supporting them in identifying and building on student resources for understanding electric circuits.

*This work is supported in part by NSF grants 1914603 and 1914572.

PS-B.08: 12:30-1:30 p.m. Investigating Transfer of Learning in an Upper-level Quantum Mechanics Course*

Poster – Alexandru Maries, Cincinnati, OH 45220

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

PS-B.08: 12:30-1:30 p.m. Scrutinize SA-Student Interaction in Inquiry-Oriented College Physics Courses

Poster – Jianlan Wang, Texas Tech University, Lubbock, TX 79409

Beth Thacker, Kyle Wipfli, Stephanie Hart, Texas Tech University

Student assistants (SA), which includes graduate and undergraduate teaching/learning assistants, are pivotal to non-traditional physics instruction in large classrooms. Despite its effectiveness, little is known about how SA-student interactions promote students' learning. How should SAs respond to students' questions? What support should SAs provide or refrain? What makes a SA effective or ineffective? We are particularly interested in SAs' questioning skills. We propose a coding scheme to scrutinize SA-student interactions. For analysis, we segment a SA video into vignettes based on different situations SAs encounter and define activities like guiding questions, probing questions, and imparting information. From the pattern of activities, we code a vignette as one of the 6 levels on the hierarchy of students' accountability. The frequency of certain levels in multiple vignettes could suggest a SA's practical knowledge of questioning, which will be compared with SAs' narrated knowledge measured by a written test of their questioning skills.

PS-B.08: 12:30-1:30 p.m. Shared Resources, Student Understanding, Spherical Unit Vectors, & Upper-Division E&M

Poster – Ying Cao, Springfield, MO 65802-3791

Brant Hinrichs, Drury University

The resources framework has been applied in physics education research in many different contexts. While it focuses on the thinking of individuals, in this work we instead apply an expanded framework called shared resources to look at three small groups as they solve problems related to spherical unit vectors in the context of upper-division E&M. Using extended examples from these think-out-loud interviews, we illustrate what we mean by this theoretical lens of shared resources: what they are, how they are shared, and what role they can play in helping students make sense of a difficult physics topic. This work builds on previous work by including more substantial and more in-depth analysis of richer examples. We conclude by drawing a few implications for possible instructional strateg

Physics Education Research IX

PS-B.09: 12:30-1:30 p.m. Affordances and Constraints of Real Experiments vs. Video

Poster – David T. Brookes, California State University, Chico, Chico, CA 95929

Eugenia Etkina, Rutgers, the State University of New Jersey

Peter Bohacek, Henry Sibley High School

Matthew Vonk, University of Wisconsin, River Falls

Anna Karelina, St. Mary's College of California

This poster describes a project in which students in an algebra-based course who learned physics through the Investigative Science Learning Environment (ISLE) approach designed and conducted experiments in labs either using real apparatus or analyzing arrays of videos pre-prepared for them. The students were assigned randomly to those two conditions. They wrote lab reports, which we analyzed using scientific abilities rubrics (Etkina et al., 2006). We present the analysis of those reports and use it to discuss the affordances of these two different ways to design experiments, collect and analyze data, test hypotheses and communicate.

PS-B.09: 12:30-1:30 p.m. Can We Teach Critical Thinking in an Introductory Lab Setting?

Poster – Stiliana Savin, Barnard College, New York, NY 10027-6598

David Weiman, Barnard College

Alisa Rod, Barnard College

Here we present results from three different assessments carried out at Barnard College. In the first, we evaluated lab reports as a part of an internal study funded by the provost's office and in collaboration with Barnard's Empirical Reasoning Center. We evaluated features like data, graph accuracy, and others, in two rounds of assessment – before and after an Excel workshop, and before and after a workshop on Experimental Uncertainty. The second assessment was done through participation in the PLIC survey. The survey presents two case studies and asks questions about models, methods, and follow-up suggestions. The third assessment was a brief one-question survey, testing understanding of experimental uncertainty, filled out during lab, pre/post instruction. The three assessments differ both in their method of evaluation and in the critical thinking skills they evaluate. We will show that the results are promising – indeed, we can teach critical thinking in the physics lab.

PS-B.09: 12:30-1:30 p.m. Development of High School Students' Understandings of Nature of Science

Poster – Matthias Ungermann, TU Darmstadt, Hochschulstraße*

Spatz Verena, TU Darmstadt

In a society characterised by STEM sciences the knowledge about Nature of Science (NOS) is deemed an important part of students' education (Höttecke, 2008; Kircher et al., 2015; OECD, 2016). Furthermore, epistemological beliefs are found to influence learning processes and learning outcomes (Hofer and Pintrich, 2016). So one can say, this seems to be a key competence for successful orientation and understanding in the STEM subjects (Köller et al, 2000). Although there are a couple of studies about students' beliefs about NOS available in some states in Germany (representing: Kremer, 2010; Ertl, 2013), due to the differing school curricula in each state generalisations are to be avoided. Therefore, we have conducted a study which explores the development of lower high school students' conceptions of NOS during one school year in the state of Hesse (N=101). On the poster we will present an overview of our results.

*Sponsored by Cyrill Slezak

PS-B.09: 12:30-1:30 p.m. Direct Observation of Student Behavior in Online Learning Modules

Poster – Matthew W. Guthrie, University of Central Florida, Orlando, FL 32816

Zachary Felker, Tom Zhang, Zhongzhou Chen, University of Central Florida

Interpretation of student behavior in online learning platforms based on clickstream data is complicated by not being able to directly observe the learner. This leads to difficulties in understanding inherently unobservable effects on the students' clickstream data. For example, we try to calculate the amount of time that each student spent studying the instructional material in each module, which requires estimating certain properties of the resulting data. Consequently, the major issue we address in this work is the difficulty of making reasonable cutoffs for abnormally short and abnormally long events. Students enrolled in introductory mechanics courses participated in a study where they completed online homework modules in a controlled, observed environment. In this talk, we will present comparisons between students' clickstream data for those who were observed and those who were not observed, and for the same student in proctored and non-proctored sessions on different modules.

PS-B.09: 12:30-1:30 p.m. It's Just Rolling Up—How Students Make Industrial Rolled-up Capacitors

Poster – Lin Ding, Department of Teaching and Learning, The Ohio State University, Columbus, OH 43210-1358

Ping Zhang, Department of Physics, Beijing Normal University

Capacitance is a challenging concept in introductory physics. Learners often struggle with the functions and working mechanisms of capacitors. In this study, we investigated how high-school students followed textbook descriptions to create industrial rolled-up capacitors. In principle, rolled-up capacitors are an extension of the 3-layer parallel-plate structure with a necessary, additional layer of dielectrics (aluminum-dielectrics-aluminum-dielectrics) to prevent short circuit and increase capacitance. Although nontrivial, the rationale and resultant outcome of the 4-layer structure is almost never discussed in textbooks. We tasked 37 students in an introductory physics class with an assignment to create and analyze rolled-up capacitors by following textbook descriptions. Findings show that the participants used the textbook descriptions merely as a cookbook recipe. They rolled up a 3-layer parallel-plate capacitor and failed to understand the mechanisms of the different layers in the rolled-up structure.

PS-B.09: 12:30-1:30 p.m. Analysis of 8 Years of Data on the NASA/IPAC Teacher Archive Research Program (NITARP)

Poster – Luisa M. Rebull, Caltech-IPAC, Pasadena, CA 91125-0001

The NASA/IPAC Teacher Archive Research Program (NITARP) partners small groups of educators with a research astronomer for a year-long authentic research project. This program aligns well with the characteristics of high-quality professional development programs and has worked with a total of 123 educators since 2005. In this poster, we explore surveys obtained from 74 different educators, at up to four waypoints during the course of 13 months, incorporating data from the class of 2010 through the class of 2017. The reasons educators participate are mapped onto a continuum ranging from more inward-focused to more outward-focused. At least 12% of participating educators have changed career paths substantially in part due to the program, and 11% report that the experience was "life changing." At least 60% are including richer, more authentic science activities in their classrooms. This work illuminates what benefits the program brings to its participants.

PS-B.09: 12:30-1:30 p.m. Patterns in Students' Self-Directed Use of the Digital Learning Environment Algodoo

Poster – Elias Euler, Lägerhyddsvägen, Sweden

Christopher Prytz, Rudbeckianska gymnasiet

Bor Gregorcic

In this poster, we present three types of activity that can be expected during students' self-directed use of a specific physics software, Algodoo, and reflect on how each activity type can be productive for the teaching and learning of physics. Unlike many commonly-used physics simulations and visualizations, Algodoo is a digital learning environment that allows students to explore a range of physics phenomena within the same software. We describe the features of the activity types, which we coded from video recordings of students as they used the software, and discuss how each of the three activity types can be seen as productive for physics education. In doing so, we provide recommendations for how physics teachers can springboard from students' engagement in each activity type into a range of possible physics-relevant discussions.

PS-B.09: 12:30-1:30 p.m. Report and Rerun: Closing the Loops in Education

Poster – Mohamed Abdelhafez, MIT, Cambridge, MA 02139

David E, Pritchard, MIT

We're developing a web-based utility to give instructors next morning formative reports on last night's assignments, including the time and difficulty on questions and videos/readings to guide today's instruction. Together with additional metadata, this information can guide revising the course for rerunning next year. Data are presented using color codes for quickly assessing how well students are doing on individual resources and on the entire assignment. This quickly identifies resources to eliminate or move elsewhere. We use "edx2bigquery" to convert edX log data into Google BigQuery which generates the dynamic reports. It also provides an easy way of adding static metadata via a popup in a modified version of open edX or directly into the resource database. These uses illustrate the desirability of "closing the loop" in education, a powerful way to improve instruction and content. The audience can suggest what information they desire - or to mohamedr@mit.edu

PS-B.09: 12:30-1:30 p.m. The NASA/IPAC Teacher Archive Research Program (NITARP)

Poster – Luisa M. Rebull, Caltech-IPAC, Pasadena, CA 91125-0001

NITARP, the NASA/IPAC Teacher Archive Research Program, gets teachers involved in authentic astronomical research. We partner small groups of educators with a professional astronomer mentor for a year-long original research project. The teams experience the entire research process, from writing a proposal, to doing the research, to presenting the results at an American Astronomical Society (AAS) meeting. The program runs from January through January. Applications are available annually in May and are due in September. The educators' experiences color their teaching for years to come, influencing hundreds of students per teacher. This poster will provide a description of the program, which has been running in this form since 2008.

PS-B.09: 12:30-1:30 p.m. Understanding Rural

Poster – Elaine Christman, West Virginia University, Morgantown, WV 26506

John C. Stewart, West Virginia University

Not all high schools prepare students equally well for university physics coursework and identifying students who may benefit from additional support can

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improve equity and access to STEM. While substantial research has investigated different outcomes for women in physics, substantially less work has investigated other students in the minority in physics classes such are underrepresented minority students, first-generation students, and rural students. This study investigates characteristics of rural schools that correlate with election of and persistence in STEM majors as well as successful completion of a calculus-based introductory physics course sequence at a large state land-grant university. Factors examined include Advanced Placement and online concurrent college course offerings, school size, and community demographic data.

Physics Education Research X

PS-B.10: 12:30-1:30 p.m. A Community of Practice Approach to Identity Formation

Poster – Claire Mullen, University College Dublin UCD, Ireland. Dublin

Brean Prefontaine, Kathleen Hinko. Michigan State University

Claudia Fracchiolla

In the last few years many studies have looked at understanding the main factors that influence discipline-based identity formation. A large number of these studies focus on identity formation from the standpoint of the individual, however research shows that identity is a social construct that is highly dependent on the environment we are emerged in. In this study, we present an operationalization of the Community of Practice framework that can be used to study identity from the collective perspective. The different elements of the framework allow us to establish the individual's positionality within the Community of Practice and the mechanisms within that community that help the individual become a more central member of the community and therefore develop a community identity. To demonstrate the use of the framework, we present findings of a study focused on the understanding of physics identity development of university students who facilitate informal physics programs.

PS-B.10: 12:30-1:30 p.m. Comparing Physics and Math Anxiety in Science Majors at University

Poster – Justin W. Hustoft, Mount Mary University, Milwaukee, WI 53222-4597

Engaging college students who are not primarily studying physics and increasing their awareness of physics-related concepts is especially important to support the decision-making processes in society. Science-major students in a general physics course on classical mechanics were given the Physics Goal Orientation Survey concurrently with the Mathematics Anxiety Rating Scale as pre- and post-course surveys. One goal was to determine how the students viewed physics and mathematics as related but separate fields. Data on physics attitudes and mathematics anxiety will establish a baseline against which future student learning outcomes and attitudes can be compared when curriculum changes in physics are implemented, such as an energy-first approach as reported in LeGresley, et al., 2019. Initial results of surveys will be presented at the summer meeting.

PS-B.10: 12:30-1:30 p.m. Ground Verification of NASA's GPM Project – DCitizen Science

Poster – Karen A. Williams, East Central University, Ada, OK 74820

NASA and JAXA have been predicting precipitation falling on the Earth for several years through the Global Precipitation Measurement (GPM) project. They are doing so by using satellites equipped with global microwave imagers as well as dual frequency radar. The satellites can sweep the planet in ninety-three minutes. This poster will show where teachers can get information about the GPM project and how they may access the data (and much more) through Giovanni software. I have done verification studies comparing their predictions to my CoCoRaHS station data. Verification of their predictions is being done by many groups. How 5G cell service will affect this project is still being argued. Students could download local data and learn about the analysis of data and how technologies are developed and tested. This could be used for outreach and to motivate students and interest the community as people of all ages are interested in the weather.

PS-B.10: 12:30-1:30 p.m. How the Learning Assistant Experience Impacts Learning Assistants as Students

Poster – Benjamin William Dreyfus, Fairfax, VA 22030

Bailey Cake, Natalie Schultz, George Mason University

Learning Assistants (LAs) are undergraduate STEM students who participate in a pedagogy course and facilitate active learning among their peers in a variety of courses. Much of the existing research on LA programs focuses on the impact on the students taking courses with LAs, or on course transformation. In addition to this, we look at the impact on the LAs themselves, as students. We asked LAs in physics, other sciences, and math to reflect on how their LA experience has affected them, through interviews with fellow LAs and free-response surveys. We analyze these qualitative data to identify emerging themes. LAs found that their LA experiences had impacts on their conceptual understanding, metacognition, time management, confidence about public speaking and working with fellow students, and relationships with professors.

PS-B.10: 12:30-1:30 p.m. Investigating Research Themes, Partnerships, and Funding for the Physics Education Research community

Poster – Rebecca J. Rosenblatt, AAAS Science and Technology Policy Fellow, Alexandria, VA 22301

Michael M. Rook, National Science Foundation

This study will inform the Physics Education Research community about patterns of research topics, partnerships between researchers, and funding sources for the PER community over the last ten years. The study involves a textual analysis of all PERC proceedings between 2010 to 2019 to identify funding sources and determine patterns. PERC proceedings were selected given the central role of the Physics Education Research Conference to the PER community. PERC proceedings represent the community across scope of project from small to large, across stage of project from beginning to finished, and from new researchers to those established in the field. Findings are contrasted with those from the Learning Sciences community to provide context for understanding the significance of patterns. The goal of this work is to provide insight into the community's history and ten-year trajectory so that the community can consider how to move the field forward in new directions.

PS-B.10: 12:30-1:30 p.m. Science of Light and Color Presented Through Examining Visual Arts

Poster – Tetyana Antimirova, Ryerson University, Toronto, ON M5B 2K3 Canada

In our modern society, art and science are often seen as unrelated, and sometimes even opposing human endeavors. However, a disconnect between science and art is finally being reconsidered, and the value of artistic creativity and imagination for careers in Science and Engineering is starting to be recognized. Moreover, an attempt to answer the question "what science ideas made their way into works of art and architecture" opens up the dialog between physicists and a general public. Examining representative artworks can be used to demonstrate the laws of physics, optics in particular. The presentation will demonstrate that the understanding of basic optics phenomena (absorption, scattering, reflection, refraction, diffraction and polarization of light) is absolutely essential for creating realistic paintings and drawings. Incorporating arts into science and engineering education and science outreach is a new approach that has the potential to captivate the audiences and unleash creativity.

PS-B.10: 12:30-1:30 p.m. The Mediating Role of Personality and Self-efficacy in Academic Achievement

Poster – Dona S. H. Hewagallage, Morgantown, WV 26505-2895

John C. Stewart, West Virginia University

This study explored the mediational relationship between personality, self-efficacy, and academic achievement in university physics and mathematics classes. The sample consisted of 9684 students primarily pursuing engineering majors at a large eastern land-grant university in the US. Data were collected from both physics and calculus classes. The five-factor model of personality was measured with the Big Five Inventory. This model characterizes personality with five facets: agreeableness, conscientiousness, extraversion, neuroticism, and openness. Significant differences in personality and self-efficacy between men and women were identified. The neuroticism facet mediated the relationship between self-efficacy and gender. Self-efficacy mediated the relationship between the course grade and conscientiousness.

PS-B.10: 12:30-1:30 p.m. The Teaching of Newton's Second Law Through Philosophical Reflection

Poster – Wilder Guerrero, Universidad Nacional de Agricultura (Honduras)

Gilberto Castrejón, CICATA, IPN of México

The results of an investigation that seeks to investigate the effects of philosophical reflection on the teaching of the concept of force in Newton's second law at the university level are presented, under the focus of conceptual change. This research has been carried out in Honduras with students of the General Physics course at the National University of Agriculture. A pre / post instrument was designed to evaluate as a didactic sequence guided by philosophical reflection and, methodologically, a mixed design has been used. In the quantitative scope, an analysis of variance (ANOVA) was made, and the preliminary results show a significantly higher performance in the experimental group. The above is supported by a qualitative analysis that shows an overcoming of the alternative conceptions of the concept of force, as well as an improvement in the students' arguments.

Upper Division and Graduate

PS-B.11: 12:30-1:30 p.m. Addressing Scientific Practices with Upper-Division Physics Assessment Items

Poster – Katherine D. Rainey, University of Colorado, Boulder, CO 80012-5715

Amali Jambuge, James T. Laverty, Kansas State University

Bethany R. Wilcox, University of Colorado Boulder

With the introduction of the Next Generation Science Standards (NGSS) in 2013, three dimensions of science learning have taken the forefront in K-12 science education: core ideas, crosscutting concepts, and scientific and engineering practices. In more recent years, researchers and educators have considered the integration of these NGSS ideas at the college level. With these three components of learning being of equal importance in these standards, it must also follow that they are equally prioritized within assessment. Scientific practices in particular can be challenging to address in assessment, as they describe what scientists actually do when they investigate the natural world (e.g., construct explanations). How can scientific practices be integrated into an upper-division college assessment that can be widely implemented and easily graded? In this presentation, we describe an initial effort in creating assessment items that address scientific practices for upper-division thermal physics students in a coupled, multiple response format.

PS-B.11: 12:30-1:30 p.m. An Application of the Physics of Viral Diffusion: COVID-19

Poster – Keith Andrew, Western Kentucky University, Bowling Green, KY 42101

Kristopher A. Andrew, Lexington Montessori High School

Eric Steinfelds, Western Kentucky University

Karla M. Andrew, Oakwood CUSD 76 School

With the impact caused by the COVID-19 pandemic, students have asked if their expertise as physics majors could be used to help understand and play a societal role in looking at the virus's impact. We explored a well-known coupled diffusion model to examine viral spread, exposure, infection, and recovery. We introduced time dependent spreading and diffusion terms that required the students to look at local data to determine parameters related to regional lockdown time, spreading rate with and without lockdown, social distancing, fraction and cultural impact for respect for obeying social distancing, diffusion constants for motorized travel, building activity and pedestrian travel, fractal dimension and anomalous diffusion. For a fixed point the system of PDEs become ODEs and when linearized near an equilibrium point the eigenvalues give a simplified algebraic expression for the reproduction number R, and herd immunity function H, to determine if the spreading is contained.

PS-B.11: 12:30-1:30 p.m. Assessing Scientific Practices in an Upper-Division Thermal Physics Course

Poster – Amali Priyanka Jambuge, Kansas State University, Manhattan, KS 66502

Katherine D. Rainey, Bethany R. Wilcox, University of Colorado Boulder

James T. Laverty, Kansas State University

Blending Scientific Practices with Core Ideas and Crosscutting Concepts (aka three-dimensional learning) as emphasized in K-12 Framework for Science Education opens up the broader scientific community's attention to bring those ideas into college courses. While these ideas are sometimes implemented in college-level classrooms as important aspects of students' learning, aligning the assessments also plays a vital role in evaluating students' understanding. Upper-division assessments largely evaluate students' understanding of conceptual knowledge in physics. However, courses similar to thermal physics that have closer proximity to real-world applications provide an avenue to explore how students intertwine their knowledge with practices. In this poster, we examine students' responses to assessment tasks developed to elicit students' abilities in blending Scientific Practices with Core Ideas (along with Crosscutting concepts) in an upper-division thermal physics course. This work addresses modifying upper-division college-physics assessments to align with three-dimensional learning.

PS-B.11: 12:30-1:30 p.m. Calculating Scientific Jargon*

Poster – Shannon D. Willoughby, Montana State University, Bozeman, MT 59717

Bryce Hughes, Jenny Green, Kent Davis, Leila Sterman, Montana State University

When writing scientific content for a lay audience, the author must take care to limit the amount of jargon that is used, so that the message is understandable. Because it can be difficult to determine what words are jargon, we have developed an R script that calculates the amount of jargon in a given piece of text. The script outputs a list of words that are likely scientific jargon, and creates a word cloud to display which words are used the most. The calculated value of jargon can be compared to benchmarked texts in order to gauge the overall difficulty versus that of ArXiv papers, classic texts, MSD sheets, abstracts of active NSF grants, and more. Frequently used jargon can be replaced or defined in order to increase readability. The R script can be downloaded from our website and can be used freely.

*This work is supported by NSF grant # 1735124

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PS-B.11: 12:30-1:30 p.m. Confessions of a Spark Plug – Sparking Children's Imagination

Poster – Jennifer J. Kirkey, Douglas College, New Westminster, BC V3L 5B2 Canada

Confessions of a Spark Plug - Sparking Children's Imagination. Thirty years of science outreach in Kindergarten to Grade Three age range has allowed me to workshop hands-on activities that manage to spark the imagination of this group, while helping to start them down the path of experimental science. A tribute to the biggest spark plug - Peter Hopkinson of the BC AAPT. This poster will present the details of what works well in my most requested presentation. Force and motion using magnets and static electricity also know as "start with a balloon". Having presented this online five times in the months of April - May - June, I will also share some tips on how to Zoom this particular topic.

PS-B.11: 12:30-1:30 p.m. Developing and Evaluating Quantum Mechanics Formalism and Postulates Survey

Poster – Emily M. Marshman, Community College of Allegheny County, Pittsburgh, PA 15212

Chandralekha Singh, 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. This work is supported by the National Science Foundation.

PS-B.11: 12:30-1:30 p.m. Exploring Graduate Students' Understanding of Entropy

Poster – Nate Crossette, University of Colorado - Boulder, Boulder, CO 80309

Michael Vignal, University of Colorado - Boulder

Bethany Wilcox

As a first step in a larger study of student difficulties in upper-division thermodynamics and statistical mechanics, we present the results of think-aloud interviews with graduate students on a set of entropy related questions. The four interview questions were developed to probe student understanding of entropy as a pressure towards equilibrium, as a quantity maximized in equilibrium, as a connection between microstates and macrostates, and as a macroscopic state-function. Exploring graduate students' understanding entropy and their ability to solve problems and reason with entropic arguments will provide insights into how physicists develop a mature understanding of entropy as a physical quantity. Specifically, we hope to see if new conceptual difficulties emerge as students progress to graduate school, and whether difficulties seen in undergraduate courses persist, evolve, or cease to present issues in the graduate setting.

SPS-B.11: 12:30-1:30 p.m. Qualitative Analysis of Students' Epistemic Framing Surrounding Instructor's Interaction.

Poster – Amogh Sirnoorkar, Kansas State University, Manhattan, KS 66506*

Christopher Hass, Kansas State University

Qing Ryan, California Polytechnic University Pomona

Alana Uriarte, DePaul University

As part of a larger study into students solving upper division problems in small groups, we investigated how instructors influence students' epistemic framing in an upper-division electromagnetism class. While existing literature indicates that instructors can influence student's epistemic framing, we are interested in the mechanisms by which that influence occurs. We use the CAMP (Conceptual, Algorithmic, Mathematics and Physics) frames in investigating dynamics of students' frames surrounding the instructor's interaction, tracking frame triplets before, during, and after instructor's intervention during tutorial sessions. We identify instructor behaviors which support students' frames and behaviors which tip them into new frames, and show how the instructor's supporting and tipping behaviors change over the course of the semester.

*Sponsored by Eleanor C Sayre

PS-B.11: 12:30-1:30 p.m. The Physics GRE Does Not Help "Overlooked" Spplicants

Poster – Nicholas T. Young, Michigan State University, East Lansing, MI 48824

Marcos D Caballero, Michigan State University, University of Oslo

One argument for keeping the physics GRE is that it can help applicants who might otherwise be missed in the admissions process stand out. In this work, we evaluate whether this claim is supported by physics graduate school admissions decisions. We used admissions data from five PhD-granting physics departments over a 2-year period to see how the fraction of applicants admitted varied based on their physics GRE scores. We compared applicants with low GPAs to applicants with higher GPAs and applicants from large undergraduate universities to applicants from smaller undergraduate universities. We find that for applicants who might otherwise have been missed (e.g. have a low GPA or attended a small school) having a high physics GRE score did not seem to increase the applicant's chances of being admitted to the schools. However, having a low physics GRE score seemed to penalize otherwise competitive applicants.

Session STPAR-1 Solo PER — Wednesday, July 22, 1:30–2:30 p.m.

Sponsor: Committee on Research in Physics Education Co-Sponsor: Committee on Professional Concerns

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 STPAR-2 Early Career Topical Discussion — Wednesday, July 22, 1:30–2:30 p.m.

Sponsor: Committee on Research in Physics Education Co-Sponsor: Committee on Professional Concerns

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.

Session STPAR-3 Student Topical Discussion and Social — Wednesday, July 22, 1:30–2:30 p.m.

Sponsor: Committee on Research in Physics Education Co-Sponsor: Committee on Professional Concerns

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 STPAR-4 Museum and Building Lobby Science — Wednesday, July 22, 1:30–2:30 p.m.

Sponsor: Committee on Science Education for the Public

STPAR-4: 1:30-2:30 p.m. Hands on with Quantum Physics

Invited – Boaz Almog Moskovich, Rehovot, Israel

Quantum physics is weird and un-intuitive. We usually imagine the classical world around us when think about physics. But in reality it is much more interesting and surprising. I will talk about my personal journey as a physics educator to take modern physics out of the lab and into the public hands. I will show how we can use hands-on demonstrations of superconductor levitation to tell the story of quantum physics. I will argue that this should be our mission as educators.

STPAR-4: 1:30-2:30 p.m. Hands-on Experience in the Lobby of Texas A&M Mitchell Physics

Contributed – Dawson Thomas Nodurft, Texas A&M University, College Station, TX 77845-6510

Each year, hundreds of people from all ages experience hands-on demonstrations in the Texas A&M Mitchell Physics Building lobby. The majority of these demonstrations are on permanent display, so anyone who happens to come to our building has a chance to interact and learn science on the way to a class, meeting, or even if they are just passing through. To encourage participation, we aim for each demo to have a common set of traits. Each demo must be eye-catching; easy to use with little instruction; give an immediate effect from use; and most importantly be fun! We will demonstrate how our exhibits achieve these results.

STPAR-4: 1:30-2:30 p.m. Particle Accelerators and Pool Balls: Integrating Big Science and Small Exhibits

Invited – Rebecca Thompson, Fermilab, Batavia, IL 60510

Education, both formal and informal, is a foundational principle of Fermilab. We have exhibits in both our iconic Wilson Hall and in the Lederman Science Center, but it can be difficult to create small, hands-on exhibits to illustrate the principles behind really big science. Merging the exhibits and site tours can give students a unique understanding of the amazing physics going on at Fermilab.

STPAR-4: 1:30-2:30 p.m. Welcome to Physics: Hallway Outreach Displays at Simon Fraser University

Contributed – Sarah Durston Johnson, Simon Fraser University, Burnaby, BC V5A 1S6 Canada

Over the last 10 years the Department of Physics at Simon Fraser University has installed a variety of science outreach displays in the main hallway leading into our building. These include hands-on physics demonstrations of electromagnetism, optics and chaos that people can try themselves. We have also installed monitors showing videos of our activities at TRIUMF and the Trottier Observatory. An additional monitor pays tribute to the generous alumni who have made donations to the department. The walls are painted with images of diagrams and equations from physics lectures, and a schematic of the TRIUMF accelerator. All of this makes for a welcoming entrance to our department that people from all walks of life, from preschool-aged children to seniors, enjoy. We will discuss how various members from the SFU Physics Dept. came together to design and build these displays, and the impact they have had on visitors to our campus.

WEDNESDAY

Session STPAR-5 SPS Undergraduate Meetup **Wednesday, July 22, 1:30–2:30 p.m.**

Sponsor: AAPT

Session STPAR-6 TYC Meetup **Wednesday, July 22, 1:30–2:30 p.m.**

Sponsor: AAPT

Session STPAR-7 Voices of Women **Wednesday, July 22, 1:30–2:30 p.m.**

Sponsor: Committee on Women in Physics **Co-Sponsor: Committee on Diversity in Physics** **Presider:** *Chandralekha SIngh*

STPAR-7: 1:30-2:30 p.m. Voices of Women in Physics

Panel – Chandralekha Singh, University of Pittsburgh, Pittsburgh, PA 15213

This panel discussion with four women physicists focuses on many topics pertaining to their physics journey.

The panelists are Ximena Cid, Geraldine Cochran, Gina Quan and Donna Stokes.

Session STPAR-9 Meet-up for Members and Supporters of the LGBTQ Community **Wednesday, July 22, 1:30–2:30 p.m.**

Sponsor: AAPT

Session STPAR-10 Retired Physicist's Meet-up **Wednesday, July 22, 1:30–2:30 p.m.**

Sponsor: AAPT

International Meet-up **Wednesday, July 22, 1:30–2:30 p.m.**

Sponsor: AAPT

K-12 Teachers Meetup **Wednesday, July 22, 1:30–2:30 p.m.**

Sponsor: AAPT

Disability Meetup **Wednesday, July 22, 1:30–2:30 p.m.**

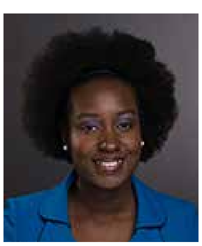
Sponsor: AAPT

Session PERC Bridging Session **Wednesday, July 22, 2:30–3:30 p.m. (LIVE Q&A)**

Sponsor: AAPT **Thursday, July 23**

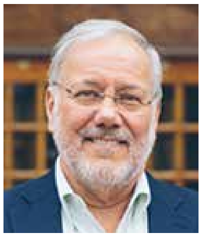
The PERC theme this year is "Insights, Reflections, & Future Directions: Emergent Themes in the Evolving PER Community." The bridging session explores the theme. The bridging session panelists represent diverse experiences in physics education research (PER) and/or discipline-based education research (DBER). To promote meaningful discourses about the history, current status and future projections of PER. Thus, the hour-long panel will be uniquely focused on communal reflections on the role of physics education research in many contexts, looking at the past, present, and future of PER.

PERC PANELISTS



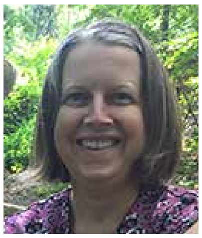
Geraldine L. Cochran, Rutgers University

Dr. Geraldine Cochran is an Assistant Professor with a joint position in the Department of Physics and Astronomy and the Office of STEM Education at Rutgers University. Cochran is a physics education researcher. Her research spans a variety of topics including course transformation in introductory math and physics courses, broadening participation in STEM, and creating collaborative and inclusive classroom spaces. Cochran is committed to equity and social justice and is active at local and national levels in addressing inequities and injustice in STEM.



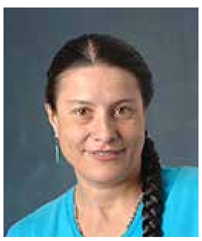
Joseph Krajcik, CREATE for STEM Institute

Joseph Krajcik serves as director of the CREATE for STEM Institute and is the Lappan-Phillips Professor of Science Education at Michigan State University. In his role as director of CREATE, he works with faculty, teachers and researchers to improve the teaching and learning of science, mathematics and engineering kindergarten through college by engaging in innovation and research. Joe served as president of the National Association for Research in Science Teaching from which he received the Distinguished Contributions to Science Education Through Research Award in 2010. In 2014 he received from Michigan Science Teachers' Association the George G. Mallinson Award for overall excellence of contributions to science education. He was honored to receive a Distinguished Professorship from Ewha Woman's University in Seoul, South Korea in 2009, Guest Professorships from Beijing Normal University in Beijing, China in 2002 and 2018, and the Weston Visiting Professor of Science Education from Weizmann Institute of Science, Israel in 2005. In 2019 Joe has been elected to the National Academy of Education, an honor received for the nation's most outstanding scholars in education.



Sarah B. McKagan, Alder Science Education Association

Sam McKagan is the creator and director of PhysPort, a website that supports physics faculty in using research-based teaching and assessment in their classes and departments. She also serves as design and development director for the Living Physics Portal, an online community for sharing and discussing materials for physics for life sciences, and the editorial director for the Effective Practices for Physics Programs (EP3) project, which is developing a guide to support physics department chairs in using effective practices for the ongoing review and improvement of their programs within the context and constraints of their local environment. She consults for universities and professional societies across the country on user-centered design, faculty professional development, and video analysis of physics classrooms.



Valerie K. Otero, University of Colorado Boulder

Valerie Otero is a professor of Science Education at the University of Colorado Boulder. She is co-founder (with Richard McCray) and executive director of the Colorado Learning Assistant (LA) program and the International LA Alliance. She has co-authored several physics curricula including Physics through Evidence, Empowerment through Reasoning (PEER Physics) and Physics and Everyday Thinking. Otero has advised the NAS, NASA, and APS on issues in physics education and physics teacher preparation. She has published broadly on physics education research and the history of physics education reform. Otero's programs use science to help learners advocate for themselves through the use of evidence. Otero is a Chicana, first generation college student, committed to building and sustaining equitable and relevant science learning environments.

Susan R. Singer, Rollins College

Prior to becoming Vice President for Academic Affairs and Provost at Rollins, Susan Singer was Division Director for Undergraduate Education at NSF and Gould Professor of Biology at Carleton, where she directed the Perlman Center for Learning and Teaching. She pursues a career integrating science and education aimed at improving undergraduate education at scale, including research on networks of organizations working to advance undergraduate STEM education. Susan is a AAAS fellow, and recipient of the American Society of Plant Biology teaching award and Botanical Society of America Charles Bessey award. She is past-chair of AAAS' Education Section and serves on the National Academies of Science, Engineering, and Medicine's Roundtable on Systematic Change in Undergraduate STEM Education and the Board on Life Sciences. She chaired the several National Academies' studies, including Discipline-based Education Research.

Robert H. Tai, University of Virginia

Robert H. Tai is an associate professor of education at the Curry School of Education and Human Development at the University of Virginia. Prof. Tai has focused his research agenda on understanding how to better engage youth in science and science learning. Through his work, he has developed tools for measuring youth science engagement in both formal and informal settings. He is currently involved with several research studies including collaborations with the Museum of Science and Industry in Chicago and the Space Science Institute in Boulder, CO. His work has been published in journals such as *Science, Science Education*, and *Journal of Science Research and Teaching.* In summer 2018, the National Afterschool Association named Dr. Tai among its "Most Influential in Research and Evaluation." He is currently Co-Editor of the *Science Educator* and on the editorial board of the *Journal Science Education and Technology.*

Meeting Participants Index