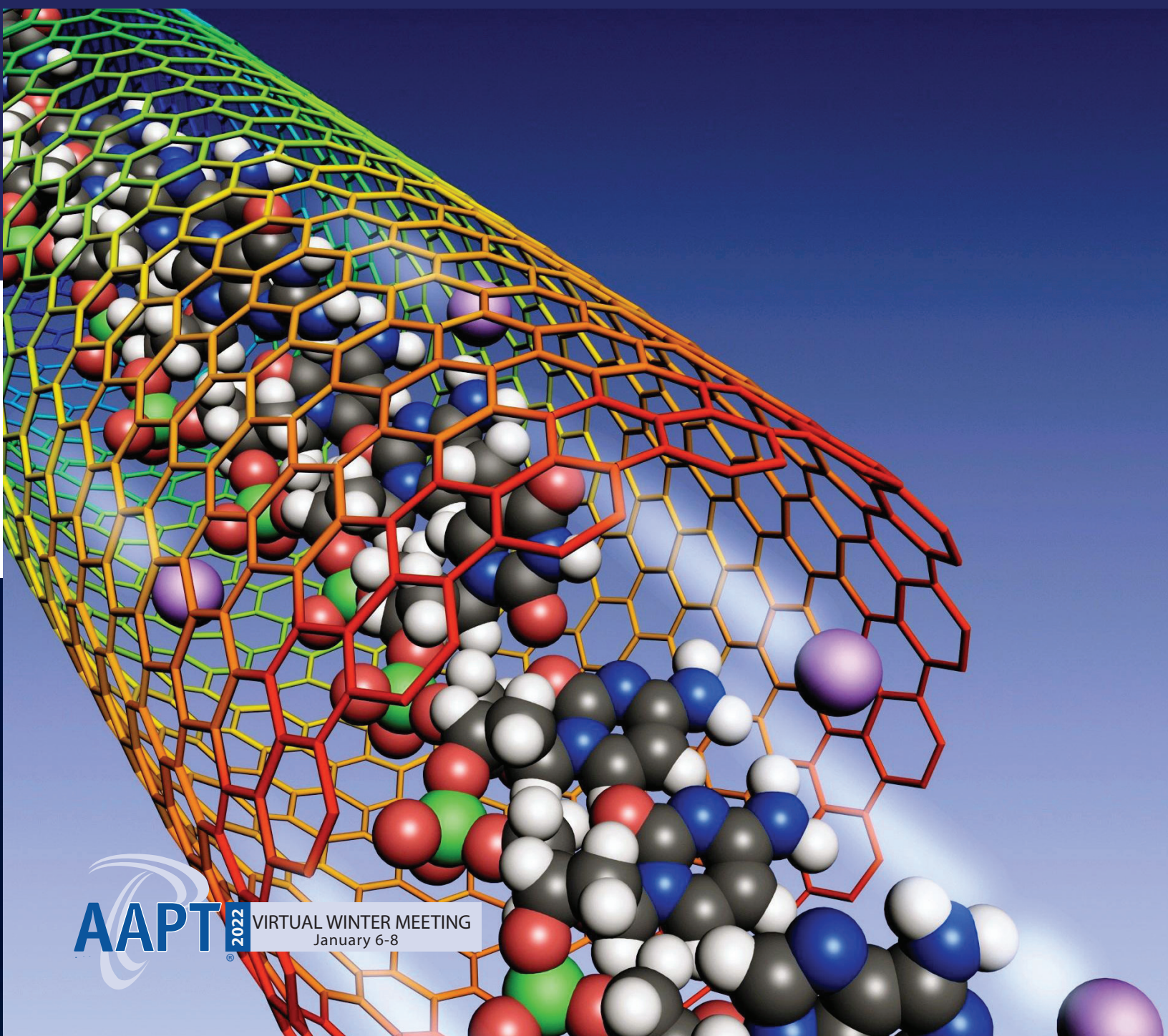


2022 AAPT

Virtual Winter Meeting



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Special Thanks

AAPT wishes to thank all the persons who helped to organize the 2022 Winter Virtual Meeting.

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Facebook/Twitter at Meeting

We will be posting updates to Facebook and Twitter prior to and during the meeting to keep you in the know! Participate in the conversation on Twitter by following us at twitter.com/AAPTHQ or search the hashtag [#aaptwm22](https://twitter.com/hashtag/aaptwm22). 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

Homer L. Dodge Citation for Distinguished Service to AAPT— Winter Meeting 2022

Arlisa Richardson

In 2008, I completed a Ph.D. in Curriculum and Instruction specializing in Science Education at Arizona State University. My research examined the impact of gender on team interactions. Before returning to graduate school in 2000 to pursue a Doctorate degree, I worked as an engineer in the semiconductor manufacturing industry. In 2011, I accepted a Physics faculty position at Chandler Gilbert Community College, where I have had the opportunity to apply my research and engineering experience in the classroom. I've also had to refresh my physics knowledge and classroom management skills. AAPT has provided the extra support, resources, and networking needed specifically for two-year college faculty. The AAPT Two-Year College group promotes successful pedagogical practices that are also beneficial to four-year colleges and universities. The exchange of knowledge and experiences is invaluable. I welcome the opportunity to be a voice for two-year college faculty within AAPT.



Arlisa Richardson

Dimitri Dounas-Frazer

Regarding his selection to receive this citation, Dounas-Frazer said, "I'm deeply grateful to the people who nominated me for this award. Volunteering for AAPT and organizing for change in physics education has been a rewarding—and often challenging—experience. Doing so has provided me the opportunity to work with and learn from diverse groups of students, staff, faculty, and other stakeholders in secondary and post-secondary contexts. I hope that the efforts I've been part of ultimately do more good than harm. Sadly, physics education has a long way to go when it comes to eradicating systemic and interpersonal ableism, racism, cis-hetero-sexism, and commitments to capitalism and colonialism." Dounas-Frazer earned his Bachelors and Masters Degrees from the Colorado School of Mines and his Ph.D. from the University of California, Berkeley. He has been a member of AAPT since 2012 and has served in various leadership positions, including as the AAPT representative to the AIP Liaison Committee on Under-represented Minorities and as the At-large Four-Year College representative of the AAPT Colorado-Wyoming Section. He has also volunteered for AAPT as the Vice Chair and then Chair for the Committee on Diversity in Physics from 2015-2017 and for the Committee on Laboratories from 2018 to 2020. He currently serves on the AAPT Nominating Committee.



Dimitri Dounas-Frazer

Dave McCahren

Regarding his selection to receive this citation, McCahren said, "AAPT & PTRAs were an important asset to my high school teaching career. I was totally surprised when notified of this prestigious award. I am humbled to be included with the recipients who continue to promote Physics and teaching at the section and national levels. Thank you!" McCahren earned his Bachelors and Masters Degrees at Indiana University of Pennsylvania and has his Teaching Certification in Pennsylvania in Instructional II Physics and Mathematics. He joined AAPT and the Central Pennsylvania Section of AAPT in 1973 and became a PTRAs in 1995, participating in the Summer Workshops each year since then. He served as Workshop Leader for National PTRAs Training Sessions in 2012 and 2017. He co-authored the PTRAs learning resource "Electromagnetic Spectrum: Window to the Universe" a workshop written in conjunction with NASA Goddard Space Flight Center. Since 1995 he has led PTRAs workshops for High School and Middle School teachers in Central Pennsylvania, Baltimore, Maryland.



Dave McCahren

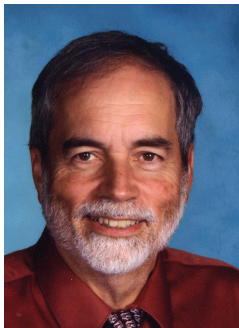
Steve Henning

Regarding his selection to receive this citation, Henning said, "It has been an honor and pleasure to serve AAPT as a PTRAs and in other capacities. I look forward to continuing to serve the physics teaching community, especially when we will meet again in person." Henning has had a very successful career as a High School Physics Teacher, teaching all levels of physics in New York state. Additionally, he served two years as an adjunct professor of introductory physics at Concordia College in Bronxville NY. What makes his career so celebrated is he was among the early innovators, who brought technology into the physics classroom as early as 1985 and shared his expertise as a leader of many workshops with his colleagues. His allegiance to his profession outside of his classroom has been focused on being active in AAPT locally, regionally, and nationally. He became a PTRAs in 1986 and attended training sessions for 23 years and plans to continue attending PTRAs training sessions. He not only served his students and fellow teachers in his school district with the PTRAs materials. He also carries out the mission of the PTRAs program by conducting workshops in New Jersey, New York City, New York State, and New England with fellow PTRAs utilizing PTRAs Manuals and materials. He remains active on the national level in the PTRAs program as a member of the PTRAs Oversight Committee. From 2006 – 2009 Henning served as the Lead PTRAs for the AAPT-PTRAs Rural Physics Teachers Workshops at Colgate University in NY. From 2016-present, he served on the Physics Master Teacher Leader Task Force. His committee service in AAPT includes the Committee on Physics in High Schools (2013-2014), Committee on Teacher Preparation (2016-2018, 2022-), Nominating Committee (2018), and the Committee for Design and Implementation of High School Video Contest (2011). Henning has served on the Executive Board of New York State AAPT Section from 2011 – present and also is a member of the New England Section of AAPT.



Steve Henning

AAPT Fellow: *Bree Barnett Dreyfuss, Pleasanton, CA*



Fred Myers

Friday, Jan. 7, 2022

1–2 p.m.

Physics for All: Wonder, Magnificence, and Joy, by Fred Myers

Raised in upstate New York, Fred Myers' formal pursuit of physics began at Vestal Central High School and continues to this day. While earning a BA in physics from SUNY Geneseo and a MA in physics at SUNY Stony Brook, he recognized that he had a passion for explaining the fundamentals of physics to others. He changed direction from his original goal of pursuing a PhD in Astrophysics and conducting research, to become a high school physics teacher.

Fred was in public and independent schools for 42 years before “retiring”. He taught physics for 33 years in a wide variety of high schools: Freeport H.S. (Freeport, NY), Choate Rosemary Hall (Wallingford, CT), Greenwich H.S. (Greenwich, CT), and Farmington H.S. (Farmington, CT) where he also served as Science Department Chair. During his last 9 years as a formal educator he served as Director of Science, an administrative position in Glastonbury Public Schools (Glastonbury, CT). In the 6 years since he “retired” he has been the Lead Subject Matter Expert for Great Minds, an innovative K-12 publishing company.

Fred is probably best known for his advocacy and leadership for the teaching/learning of the “right-side-up” science sequence in high school ... often called physics first. He taught physics to 9th graders (and younger) for a total of 27 years.

Other professional leadership roles include being co-founder and president of the Connecticut Association of Physics Teacher, president of the Association of Presidential Awardees in Science Teachers, president of the Connecticut Science Supervisors Association, and a Fellow of the Project to Improve Mastery in Math and Science. Major awards have included the Presidential Award for Excellence in Science Teaching, Milken Family Foundation Award, AAPT's Janet Guernsey Award, and the Christa McAuliffe Award.

ABSTRACT

Physics educators should strive to reach a far greater percentage of the populous. A wider appreciation and understanding of the laws of physics will help produce a better, more informed citizenry. It behooves physics educators to develop and implement introductory physics courses that are relevant, interesting, inspiring, and joyful ... all while setting high expectations for achievement.

Everyone experiences physics in their everyday lives during childhood (from motion to magnets) and begins developing concepts about them. Sadly, only a very low percentage of humans enroll in a formalized physics course during their schooling, and an astonishingly low percentage enroll in a second physics course.

Far too many students avoid physics courses in school because they've heard it is very difficult, boring, hard to understand, and “just another math course”. Physics educators at all levels should strive to make a student's first physics course engaging, interesting, challenging, and fun. Physics is for everyone and should not be treated as an elite course that is reserved for the best and the brightest students. A first-rate introductory course should challenge students' minds and open their eyes to the magnificence of physics, and leave the students desirous of learning more physics.

ABSTRACT

The quest to achieve ethnic and gender equity in physics has been a goal for at least the past fifty years. Despite the resolute and well-intended efforts of so many people and organizations, parity has alluded us. While there has been success in raising the numbers of African Americans in the field, we have lost ground in terms of overall representation. We were elated to see significant increases in percentages of women earning degrees, rising from single digits to just above twenty percent; but those numbers have plateaued well short of parity. It is encouraging to see the steady increase in the Latinx representation as we mine those numbers extracting the lessons learned that might be adapted in a broader context. While there is a compelling argument for the need to address the broad underrepresentation in physics, this talk will focus on the underrepresentation of African Americans in the discipline. My journey began in 1964 at Virginia State College as an instructor in an NSF sponsored program to improve the science education of K-12 teachers. My thinking about solutions in over fifty years of active engagement has evolved from believing “It's just the science” to recognition of the need for a more comprehensive approach. This talk will revisit that fifty-plus year journey by focusing on what I think are key issues. Among these: Are we asking the right questions? Are we solving the right problem? What is our definition of success?



James H. Stith

Saturday, Jan. 8, 2022

2:30–3:30 p.m.

Dr. James H. Stith, Diversity, Equity, and Inclusion: An Elusive Goal?

James H. Stith is a former president of the American Association of Physics Teachers (AAPT) and Vice President Emeritus of the American Institute of Physics (AIP). Throughout his career, he has been an advocate for programs that ensure ethnic and gender diversity in the sciences. As Vice President, he had oversight of a broad portfolio of units which included the Magazine Division, the Media and Government Relations Division, the Education Division, the Center for the History of Physics, the Statistical Research Division, and the Careers Division, all of which provided day to day support of AIP Member Societies. His doctorate in physics

(Continued on next page)

The James Webb Telescope by Matthew Greenhouse

Matthew Greenhouse has served on the James Webb Space Telescope senior staff as Project Scientist for the Webb science instrument payload since 1997. He specializes in infrared imaging spectroscopy, development of related instrumentation and technologies, flight project science, and technical management.

Greenhouse began work in infrared astronomy during 1979 when, after receiving a Bachelor's of Science degree in Geosciences from the University of Arizona, he joined the Steward Observatory as an instrument technician for balloon-borne and Kuiper Airborne Observatory science instrument development. During 1983, he joined the Wyoming Infrared Observatory as a graduate student in physics. After receiving a Ph.D. in Physics from the University of Wyoming during 1989, he joined the Smithsonian Institution in Washington DC as a Federal Civil Service astrophysicist. He then joined the NASA Goddard Space Flight Center during 1996 in the same capacity.

Greenhouse has served on several NASA and European Space Agency (ESA) flight mission teams. He supported ESA's Infrared Space Observatory mission as a member of the Long Wavelength Spectrometer instrument team. He supported the NASA Stratospheric Observatory for Infrared Astronomy mission by serving on its Independent Annual Review Board as Co-Chair, and served on both its Interim Management Review Board, and Science Steering Committee. He supported the NASA Spitzer mission by serving on its Community Task Force as Legacy Science Program Chair and the Hubble Space Telescope Wide Field Camera 3 instrument project by serving on numerous gateway technical review boards. Greenhouse has been a member of the NASA Astrophysics Working Group, and has supported ground-based astronomy through membership on the National Science Foundation Committee of Visitors, and numerous selection committees and review boards for major ground-based instrumentation.

Greenhouse is the recipient of more than 20 individual performance awards and honors including: the NASA Exceptional Achievement Medal and the Robert H. Goddard award for Exceptional Achievement in Science.

Greenhouse's post-graduate professional training includes completion of more than 20 courses in technical management, public leadership, and engineering from the Brookings Institution, The University of California Los Angeles, the NASA Academy of Program/Project & Engineering Leadership, and the Federal Executive Institute. Greenhouse received a Certificate in Public Leadership from the Brookings Institution during 2012.

(Continued from page 4)

was earned from The Pennsylvania State University, and his master's and bachelor's degrees in physics were received from Virginia State University. A physics education researcher, his primary interests were in Program Evaluation, and Teacher Preparation and Enhancement. Dr. Stith, whose academic career started as an instructor at his alma Mata, VSU, is a retired Army Colonel and was formerly a Professor of Physics at the United States Military Academy (West Point), and The Ohio State University.



Matthew Greenhouse

ABSTRACT

The James Webb Space Telescope is the successor to the Hubble Space Telescope. It is the largest space telescope ever constructed, and will extend humanities' high definition view of the universe into the infrared spectrum. The Webb will observe early epochs of the universe that the Hubble cannot see to reveal how its galaxies and structure have evolved over cosmic time. The Webb will explore how stars and planetary systems form and evolve and will search exoplanet atmospheres for evidence of life. The Webb's science instrument payload includes four sensor systems that provide imagery, coronagraphy, and spectroscopy over the near- and mid-infrared spectrum. The JWST is being developed by NASA, in partnership with the European and Canadian Space Agencies, with science observations proposed by the international astronomical community in a manner similar to the Hubble. The Webb is in the final stages of preparation for launch during 2021.

Saturday, Jan. 8, 2022

10–11 a.m.

Plenary I - Fred Meyer, Physics for All: Wonder, Magnificence, and Joy, 1–2 p.m.

Exhibitor Meetups, 2–3 p.m.

Session A1: 21st Century Physics in the Classroom Friday Jan. 7, 3–4 p.m. Moderator: Shane Wood
Sponsor: Committee on Physics in High Schools

A1-01 - 3:00 p.m. | Invited | Incorporating Coding into High School Physics and Astronomy

Presenting Author: Christine DiMenna, Gilman School

Additional Author: Tiffany Coke, Punahou School

Bring coding into your physics classes in small doses, with easy-to-use lessons on topics you already teach. The Coding Fellows from Quarknet have developed a free, editable curriculum designed for a range of students/grade levels and is aligned to NGSS and AP/IB standards. These physics and astronomy lessons address core science topics such as energy conservation, the HR Diagram, and projectile motion as well as topics in nuclear and particle physics. On the tech side, it uses Python, Jupyter, and cloud or locally installed platforms that don't require explicit instruction on computer science principles to be useful for your students. Short, easy-to-follow intro lessons lead students on their own to adapt to the coding environment. Learn about these curriculum resources and professional development opportunities to grow your own skills as well as to adapt the curriculum for your own courses.

A1-02 - 3:30 p.m. | Invited | QuarkNet Masterclasses: Students Become Particle Physicists for a Day

Presenting Author: Paul Sedita, Canandaigua City Schools

Presenting Author: Jeremy Wegner, Winamac Community High School

Each year more than 13,000 high school students around the world gather in-person or virtually at one of over 200 universities or research laboratories to become "particle physicists for a day" where they are immersed in 21st-century physics research to learn about the world of quarks and leptons. This presentation will outline the features of these Particle Physics Masterclasses, give examples of masterclass measurements, describe how these activities connect to introductory physics concepts and how to become involved in this exciting collaboration. One such masterclass focuses on neutrino data from the MINERvA experiment at Fermilab, and another masterclass focuses on data from the CMS detector at the Large Hadron Collider.

Session A9: Assessing and Improving Equity in Physics Learning Environments I Friday Jan. 7, 3–4 p.m.
Moderator: Alexandru Maries Sponsor: Committee on Women in Physics

A9-01 - 3:00 p.m. | Invited | Ecological Belonging Interventions to Improve Equity and Inclusion in Physics

Presenting Author: Emily Marshman, University of Pittsburgh

Additional Author | Chandralekha Singh, University of Pittsburgh

Additional Author | Yasemin Kalender, Harvard University

Additional Author | Kevin Binning, University of Pittsburgh

We will discuss how ecological belonging interventions can be adapted and implemented in physics classes to make them more equitable and inclusive. These types of interventions are short, requiring less than one hour of regular class time even though they have the potential to impact student outcomes significantly—especially for underrepresented students in physics classes. We will present data from large introductory physics courses showing the efficacy of such interventions.

A9-02 - 3:30 p.m. | Invited | Identity Perspectives from a Latina Woman in Physics

Presenting Author: Idaykis Rodriguez, Florida International University

As a Latina woman in physics I have experienced extreme doubt under imposter phenomena and deficit thinking. Questioning if I am even actually a physicist. It's been quite the journey to learn that I am not alone in these thoughts and experiences, and now even have had to relearn how to exist in a space outside the "typical physicist". Taking my story as a guide I share the introspective research process of a duoethnography and how it redefined my identity spaces. Understanding my dual existence as both marginalized and privileged in physics, I turn to the guiding framework of Critical Chicana Feminists, Gloria Anzaldúa concepts of Nopantla (the land in the middle) to help conceptualize intersectionality in my identity spaces. Taking my dualities in being, will focus on reconceptualizing how we practice physics in the classroom, in research, and in mentoring for marginalized students.

Session A3: Biophysics in the 21st Century Curriculum I Friday Jan. 7, 3–4 p.m. Sponsor: Committee on Contemporary Physics
Co-Sponsor: Committee on Physics in Undergraduate Education Moderator: Mariel Meier

A3-01 - 3:00 p.m. | Invited | Integration of Biomedically Relevant Content in Introductory Physics Instruction*

Presenting Author: Priya Jamkhedkar, Portland State University

Additional Author | Mayuri Gilhooly, Rockhurst University

Additional Author | Nancy Donaldson, Rockhurst University

Additional Author | Ralf Widenhorn, Portland State University

The need to reform pre-medical and life science physics curricula has been stated in several publications and expert panel reports. At Portland State University (PSU) and Rockhurst University (RU) we are in the process of designing a full-year introductory physics curriculum to specifically engage pre-health students and foster an appreciation of the study of physics as both necessary and relevant to their future careers in medicine. It aims to provide students with a curriculum that stresses the importance of physics as a basic science relevant to medicine. The goal is to provide faculty unfamiliar with biomedically related interdisciplinary content with a coherent physics curriculum that can be implemented in multiple educational environments. During the 2020-2021 pandemic impacted school year we implemented part of the curriculum as all online (PSU) and mixed classroom (RU) courses. We will present early results from this implementation and discuss future design and implementation plans. *This work is supported by the grants DUE- 1934038 and DUE- 1933984 from the National Science Foundation.

A3-02 - 3:30 p.m. | Invited | Biomedical Physics for Undergraduate STEM Majors

Presenting Author: Mary Lowe, Loyola University Maryland

Administered by the physics department, a biomedical physics minor was implemented at Loyola University Maryland. Two courses were developed: one on sport and biomechanics, and the other on therapeutic and diagnostic techniques in medicine. While most of the materials are at the intermediate-level, appropriate for students majoring in various STEM disciplines, the materials can be adapted for introductory and advanced levels. Lectures, reading, and problem sets are enriched with experimentation, demonstrations, paper-and-pencil, and computer activities. This talk will survey many of the course topics and how we have introduced modeling in the courses. Examples include fiber optics in medicine, computed tomography, positron emission tomography, and gamma camera imaging. For biomechanics, examples will be drawn from a dissection, metabolic efficiency, biomechanics of the arm, leg, and back, analysis of simple motions in sports, and the heart as a pump.

*This work was initially supported by NSF TUES Award No. DUE-1140406.

Session A2: Frontiers in Planetary Science I

Friday Jan. 7, 3–4 p.m.

Moderator: David Klassen

Sponsor: Committee on Space Science and Astronomy

A2-01 - 3:00 p.m. | Invited | The OSIRIS-REx Mission

Presenting Author: Harold Connolly Jr., Rowan University

OSIRIS-REx is NASA's New Frontiers 3 asteroid sample return mission. Launched in September 2016, the spacecraft arrived at its target asteroid 101955 Bennu in December of 2018. The surface of asteroid Bennu was then investigated down to the sub-centimeter level with the goal of finding a suitable site to collect at least 60 g of asteroid regolith. The primary and backup collection sites, Nightingale and Osprey respectively, were announced in December 2019. On October 22, 2020, the OSIRIS-REx spacecraft successfully collected regolith from the surface of Bennu, storing it in the Sample Return Capsule (SRC) just a few days later. OSIRIS-REx left Bennu on May 10th, 2021 and is currently on a journey to return sample to Earth on September 24, 2021. After successful recovery of the SRC, samples will be processed at NASA Johnson Space Center for analysis with a goal of constraining the history of Bennu.

A2-02 - 3:30 p.m. | Invited | Planets in a Bottle: Exploring Planetary Atmospheres in the Lab

Presenting Author: Sarah Hörst, Johns Hopkins University

As we push to expand our understanding of planetary atmospheres beyond the Solar System, we increasingly encounter challenges because we lack a fundamental framework to understand the chemistry that occurs in those atmospheres, particularly as it relates to the formation of particles from chemistry that occurs in the gas phase. We use can use laboratory simulations of planetary atmospheres to try to overcome some of these issues and leverage what we've already learned from more than 50 years of planetary exploration. Here I will discuss the work done in my laboratory to understand planetary atmospheric chemistry and the ways in which we use laboratory work to improve our understanding of planets both inside and outside our solar system.

Session A5: Inclusive Science Communication

Friday Jan. 7, 3–4 p.m.

Moderator: Juan Burciaga

Sponsor: Committee on Women in Physics

A5-02 - 3:00 p.m. | Contributed | Assessing an Oral Communication Course for STEM Graduate Students

Presenting Author: Shannon Willoughby, Montana State University

Additional Author | Bryce Hughes, Montana State University

Additional Author | Brock La Meres, Montana State University

Additional Author | Leila Sterman, Montana State University

In an NSF IGE funded study, our group developed and refined a curriculum for teaching oral communication skills to STEM graduate students at Montana State University. Through three iterations, with 22 student fellows total completing the program (16 of whom identified as women), we have assessed the curriculum for this course. Using a 3C framework of connect, convey, captivate, we find that fellows who have completed this program are more likely to reduce their use of jargon, and to carefully consider their audience when developing a storytelling strategy and creating analogies. Further, after regular practice playing improvisation games, the fellows are more comfortable answering questions from diverse audiences. Finally, we have found that anxiety levels about public speaking either remain constant or increase slightly. We will discuss these findings, and student feedback regarding the effectiveness of the instruction.

A5-03 - 3:10 p.m. | Contributed | What Values do Teachers and Researchers Balance in Curriculum?

Presenting Author: Katarzyna Pomian Bogdanov

Science curriculum is often thought of as laying within a historical and social vacuum with a focus primarily on the scientific accuracy of the subject matter as opposed to a focus on students and equitable science education. This study explores the curricular values that arise while teams of researchers and teachers co-design a high-school physics unit from a student-lead mindset. The participants in co-design bring their expertise into the work to create curricula that benefit from both the knowledge of the researchers and the expertise of the teachers working within the field in efforts to create more sustainable curricula. We find curricular values that arise, lay within four major clusters including subject matter, audience, alignment and equity focused science education. A deeper examination of the moments when tensions arise shows competing priorities of participants in balancing these curricular values.

A5-04 - 3:20 p.m. | Contributed | The Thermodynamic of Disasters of the Climate Crisis

Presenting Author: Frank Lock, Climate Reality Project

Increasing the entropy of our planet may be a prime driver in the climate crisis we are all facing. This presentation will introduce evidence for this idea. Participants will receive information about lessons they can use to introduce students to the challenges of the climate crisis.

A6-01 - 3:00 p.m. | Invited | Spreadsheets & Computation in the Lab: Introductory Courses and Beyond

Presenting Author: Jennifer Birriel, Morehead State University

In many physics teaching labs all calculations are still done by hand: students repeatedly calculate the same quantity for multiple trials using a calculator and write computed values onto a paper table. Why do this? Does it help the student understand physics better? Surely, students' time can be better spent analyzing experimental results, examining experimental uncertainties, and learning some basic computing! Spreadsheets are a nearly ideal computational tool for data reduction and analysis as well as modelling in the physics lab. We will discuss the similarities of spreadsheet computing to programming languages including syntax, algorithm development, compiler and runtime errors, calling on functions, passing variables, and controlling output format. Additionally, we will look at some useful features of Excel plotting and trendline fitting. We'll look at some examples of spreadsheet computation in both introductory and advanced physics laboratory courses.

A6-02 - 3:30 p.m. | Invited | Computation in Introductory Physics Labs Using Argument Driven Inquiry

Presenting Author: Steven Wolf, East Carolina University

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) using the curricular format _Argument Driven Inquiry_ (ADI). We now use this curriculum in both online and face-to-face lab formats. Neither implementation of this curriculum (online or face-to-face) would be possible without using computers to collect, analyze, and present data. I will discuss how we are using computers in the context of this course, present examples of some of the tasks used, and include some information about how we assess these lab courses.

A7-01 - 3:00 p.m. | Invited | Lobby and Hall Way Physics Engaging the Walk Through Crowds

Presenting Author: Duane Merrell, Brigham Young University

A look at the pendulum court and hallway science demonstrations in the Brigham Young University, Eyring Science Center.

*Some of the fun demonstrations.

*Who and how the demonstrations are cared for, the people who really make this work.

*The idea of interaction with science question and apparatus.

A7-02 - 3:30 p.m. | Invited | Lederman Science Center at Fermilab

Presenting Author: Ketevan Akhobadze, Fermilab

Particle physics shapes our view of nature in a fundamentally new way. Unfortunately, most students in today's public schools never have a chance to learn about the strangeness and beauty of the world of elementary particles. At Fermilab's Lederman Science Center (LSC) we create interactive hands-on exhibits, virtual activities, and educational videos that explain how scientists study very small objects (like quarks and neutrinos) that cannot be directly observed or measured. Our exhibits introduce people to the basic concepts behind Fermilab's science—scale of the universe, symmetry in nature, fundamental particles and forces, accelerators and detectors. Currently we are setting up a MakerSpace—a safe, free, collaborative workspace with all necessary materials and resources for open-ended education experiences. The goal is to provide a space at LSC for learners of all ages and backgrounds where they can get engaged in activities that foster creativity, interest, and skill development inspired by Fermilab's science.

Session A12: Pandemic Reflections Topical Discussion Friday Jan. 7, 3–4 p.m. Moderator: Reed Prior

Sponsor: Committee on Physics in High Schools

Discussion on challenges and successes within teaching during COVID.

Session A10: Physics and the Arts I Friday Jan. 7, 3–4 p.m. Moderator: Joe Kozminski

Sponsor: Committee on Science Education for the Public

A10-01 - 3:00 p.m. | Invited | Using Music to Teach Waves

Presenting Author: Gordon Ramsey, Loyola University Chicago

Sound and music are governed by the properties of waves. They provide motivating topics for learning many subjects, from music to physics. Studies have shown that active student involvement is important in science education for helping the students understand physical concepts. These results imply that music and acoustics are perfect avenues for teaching wave property concepts. This approach gives students a meaningful connection of waves to every-day experience. Even at the college level, non-science majors can understand how music and physics are related through the understanding of wave phenomena. There are many demonstrations, laboratory investigations and hands-on group activities that can be done at all educational levels in this area. This paper suggests ways to incorporate sound and music to present waves at many levels.

A10-02 - 3:30 p.m. | Invited | Whose Idea Is it Anyway?

Presenting Author: Carolyn Sealfon

Interactions are fundamental to physics, be they physical forces between systems or social dynamics between humans. How can we help all our students experience what we love about physics, such as the playful curiosity and the wonder of exploration? Let's create a camaraderie-filled laboratory to test assumptions underlying our interactions with each other and with physics. Join us to apply the tools and techniques of improvisational theater (improv) in this laughter-filled interactive session. We will discuss how we can integrate and adapt improv exercises to enhance physics teaching and learning, including connections with the Investigative Science Learning Environment (Etkina et al.) approach. (Title is courtesy of collaborator Nancy Watt.)

Session A4: Quantum Education at the K-12 Level I Friday Jan. 7, 3–4 p.m. Moderator: Chandralekha Singh

Sponsor: Committee on Science Education for the Public / Co-Sponsoring: Committee on Physics in High Schools

A4.01 - 3:00 p.m. | Invited | Quantum Resources for K-12 and Beyond

Presenting Author: Emily Edwards

In the Fall of 2020, the National Q-12 Education Partnership was launched and numerous programs for quantum workforce development came online. In the long-term, emerging programs have the potential to help young learners develop an appreciation for quantum information science and engineering (QISE), and even inspire students to pursue a career in this critical area. In addition, introducing QISE concepts early in schools will enable students to build intuition around this topic, and better prepare them for future QIS coursework at the undergraduate level. Extending QISE learning opportunities to younger age groups is also critical towards growing a more inclusive, diverse quantum workforce and engaged quantum-aware public. I will give an overview of the current status of resources for K-12 learners, educators, and stakeholders, as well as the need to address certain challenges in this ecosystem.

A4.02 - 3:30 p.m. | Invited | High School Teacher PD; Building Capacity to Next Quantum Workforce

Presenting Author: Mark Hannum, AAPT

Introducing Math, Computer Science, and Physics Teachers to QIS topics is the first step to building the next quantum workforce. By learning how to integrate these exciting new topics into their existing course, teachers can keep their content current and inspire all of their students to see a future working with QIS. This session will outline the structure and content of the Professional Development that AAPT has been implementing over the last 12 months online and in person. These workshops make significant use of the IBM Qiskit system and Jupyter notebooks to guide participant teachers through tutorials on fundamental quantum mechanics and quantum computing.

Session A8: Quantum Mechanics I Friday Jan. 7, 3–4 p.m. Moderator: TBA

Sponsor: Committee on Physics in Undergraduate Education

A8-01 - 3:00 p.m. | Invited | Innovative Learning in Quantum Physics; Objectives, Content and Methods

Presenting Author: Kirsten Stadermann, University of Twente, Netherlands

We are currently experiencing the so-called second quantum revolution (with buzzwords like quantum optics, quantum materials, quantum cryptography, quantum internet). At the same time, pseudo-spiritual and commercial quantum quackery (e.g. quantum dishwasher tablets, quantum dating, quantum peace) is also flourishing. Both are reasons why many countries consider it important that young students learn about quantum physics. Not only quantum physics itself but also the learning objectives, content and methods have been revolutionized in recent decades. Innovative teaching alternatives to the infamous "shut up and calculate" approach make quantum physics accessible to all students from middle school to college. These approaches do not use complex formalism. They show students that quantum physics is not incomprehensible magic but real and useful science. I will present a selection of suitable approaches for different target groups, for example, to make quantum phenomena tangible or to address aspects of Nature of Science.

A8-02 - 3:30 p.m. | Invited | UK Quantum Education and Skills Needed by the Quantum Industry

Presenting Author: Michael Fox, Imperial College London

Additional Author | H J Lewandowski, University of Colorado Boulder

Additional Author | Ben M Zwickl, RIT

The Quantum Revolution has been making headlines over the past few years. I will present the results from interviews with US companies in the Quantum Industry on the skills and knowledge they are looking for in their employees. From my current position, I will give an overview of the quantum education landscape in the United Kingdom, from high school through to postgraduate degrees. This will then allow me to comment on how the UK system relates to the skills and knowledge needed by the Quantum Industry.

Session A11: The International Conference on Women in Physics Panel Friday Jan. 7, 3–4 p.m.

Moderator: Laura McCullough **Sponsor:** Committee on Women in Physics

Panelists will share stories and successes from the recent International Conference on Women in Physics (ICWIP), held virtually in July 2021. These conferences are held every three years and are sponsored by the International Union of Pure and Applied Physics. Delegates from the US were part of poster sessions and workshops, and were able to listen to multiple plenary speakers from around the world. ICWIP draws approximately 200 people, primarily women, from over 60 countries and helps promote women in physics and sharing their struggles and successes.

Session A1.1: 21st Century Physics in the Classroom II Friday Jan. 7, 4:15–5:15 p.m.

Moderator: TBA **Sponsor:** Committee on Physics in High Schools

A1.1-01 - 4:15 p.m. | Contributed | Computation-based Spins First Quantum Mechanics for High School*

Presenting Author: Abby Pruett, University of North Florida

Presenting Author | W. Brian Lane, University of North Florida

Presenting Author | Terrie M. Galanti, University of North Florida

Our students' careers will touch on quantum concepts in ways we might not anticipate, yet the learning of quantum mechanics largely remains separated from the high school physics experience where students first form expectations of how they might use physics throughout their lives. Two primary barriers to integrating quantum into the high school context are conceptual challenges and mathematical formalism. We outline how these barriers can be lowered by adopting a computationally integrated spins-first approach. We have begun introducing this approach to a cohort of high school physics and chemistry teachers with the goal of introducing a supplemental quantum unit in the teachers' classes at the end of the school year and tracking the adaptations required to deliver this experience to high school students. We present the structure of our professional development activities and report on the successes and challenges thus far.

*This work is supported by the VOYA Foundation.

A1.1-02 - 4:25 p.m. | Contributed | The Search for Dark Matter

Presenting Author: Margaret Norris, Black Hills State University

The idea of dark matter sparks the imagination of students of all ages, and the Education and Outreach team at SURF takes full advantage of their curiosity to teach core content in physical and space science, engineering, the science and engineering process and crosscutting concepts of science, such as scale. A sweet spot for dark matter related content is middle school, and at SURF we engage middle school students with interactive presentations, virtual tours and an in-depth curriculum unit featuring forces and interactions and indirect evidence. Students learn how 'normal' matter interacts with light, how our understanding of gravity led to the first evidence for dark matter and how Einstein's theory of general relativity leads to the most compelling evidence for dark matter to date. They explore candidates for dark matter and how the LZ detector is designed to be sensitive to WIMPs (Weakly Interacting Massive Particle).

A1.1-03 - 4:35 p.m. | Contributed | Curated Cosmic Ray Files for High School Laboratories

Presenting Author: Nathan Unterman, QuarkNet

Since 1999, QuarkNet has trained teachers and students in high energy physics by deploying cosmic ray muon detectors to high school classrooms. Students of QuarkNet teachers show evidence that they understand how scientific knowledge is developed and engage in scientific practices and discourse. A curated set of data files has been established for analysis in classrooms that do not have detectors. Muon speed (two methods), angle of acceptance and flux, muon lifetime, and shower studies are some of the data sets available. Novice level activities to advanced studies will be discussed using the speed of a muon experiment as an exemplar. Emphasis on graphical analysis, histograms, error analysis and other techniques will be demonstrated showing alignment to NGSS Standards.

A1.1-04 - 4:45 p.m. | Contributed | Classroom Tool for High Energy Physics Analysis: QuarkNet e-Lab

Presenting Author: Mark Adams, Fermilab

Additional Author | Nathan A Unterman, New Trier High School, Winnetka, IL

QuarkNet's Cosmic Ray e-Lab provides an online environment in which students experience the excitement of scientific collaboration in this series of investigations into high-energy cosmic rays. Schools with cosmic ray muon detectors upload data and use the eLab for data analysis. The format allows schools that do not have detectors to participate in research by analyzing shared data. A brief overview of different analysis tools will be presented.

A1.1-05 - 4:55 p.m. | Contributed | Incorporating Climate Change Consequences and Solutions into Introductory Physics Classes

Presenting Author: Charli Sakari, San Francisco State University

Climate change is increasingly becoming a hard reality as we move into the 21st century. As educators of physics and astronomy, we can offer a unique perspective on climate change consequences and solutions. In this presentation I will include a few suggestions of how climate change consequences and solutions can be incorporated into introductory physics classes. I will also introduce Astronomers for Planet Earth (A4E), a grass roots organization of professional astronomers, educators, students, amateurs, and outreach specialists who are dedicated to using the astronomical perspective to fight climate change. The A4E Education Working Group is dedicated to curating and developing pedagogical resources for educators in physics and astronomy; I will discuss how to join A4E and contribute to and use these valuable resources.

Session A9.1: Assessing and Improving Equity in Physics Learning Environments II Friday Jan. 7, 4:15–5:15 p.m.

Moderator: TBA Sponsor: Committee on Women in Physics

A9.1-01 - 4:15 p.m. | Invited | Data to Improve Equity in Physics and Astronomy Classrooms*Presenting Author: Rachel Ivie, American Institute of Physics*

The American Institute of Physics (AIP) collects data on the representation of women and members of other underrepresented groups in physics and astronomy at all levels, from high school students to faculty members. Although indicative of some trends, these data do not tell the whole story. For physicists and astronomers who persist despite being underrepresented, data show that there are additional barriers to equitable participation. For example, AIP's TEAM UP report documents factors that contribute to the low numbers of Black undergraduate students in physics and astronomy. A recent AIP study of the effects of COVID on undergraduate physics and astronomy students showed more negative effects for those who are from marginalized groups than for those who are not marginalized. Data on areas of inequity in physics learning environments are essential so that we may design programs and practices that will allow full participation for all.

A9.1-02 - 4:45 p.m. | Invited | Graduation Rates of Women in the US and UK*Presenting Author: Angela Johnson, St. Mary's College of Maryland**Presenting Author | Jaimie Miller-Friedmann, University of Birmingham**Presenting Author | Jessy Changstrom, Kansas State*

Sneak peek at data we will release publicly in 2022: the physics graduation rates of women from historically excluded groups, at all US and UK institutions. US data includes institutions that are above average, average or below average for all women; all women of color; and Black, Indigenous and Latinx women. Users can also construct custom comparison groups. UK data classifies institutions by representation of Black and minority ethnic women among the student body and faculty, rate at which Black and minority ethnic women are hired upon graduating, and Athena Swan standing. This portal will allow physics departments to track their performance; will provide vital information to women who are considering joining particular institutions; and will allow researchers to identify trends among better-performing institutions. We anticipate intense interest in the portal as soon as it is made public; this is your chance to get a preview.

Session A3.1: Biophysics in the 21st Century Curriculum II Friday Jan. 7, 4:15–5:15 p.m.

Moderator: TBA Sponsor: Committee on Contemporary Physics / Co-Sponsoring: Committee on Physics in Undergraduate Education

A3.1-01 - 4:15 p.m. | Invited | Transitioning Students from Learning Biophysics to Doing Biophysics*Presenting Author: Brian Cannon, Loyola University Chicago*

The Loyola University Chicago Department of Physics offers a B.S. in Biophysics program that consists of a balanced blend of biology, chemistry, and physics coursework. As a capstone experience, students must complete an upper-level biophysics course. Although the course has a significant lecture component with a focus on molecular and cellular biophysics as well as biomechanics, the aim of the course is for students to engage in professional science activities. Classroom activities include interpreting results from journal articles, writing an NIH-style research proposal on an instructor-approved topic with peer reviews, and completing an experimental project. I will present an overview of the course, its activities, and challenges. Students are also encouraged to participate in faculty research, and my undergraduate-only lab has several student researchers conducting experiments in single-molecule DNA microscopy. I will also discuss how the lab recruits students, trains them for research, and mentors their progress.

A3.1-02 - 4:45 p.m. | Contributed | Physics for the Modern World*Presenting Author: Donald Franklin, Retired/ consult for Openstax.college*

Using Openstax.college available ebooks, I built an ebook that incorporates the topics the Pre Med students need, not the syllabus used by most major textbooks. My major position is " Don't Teach What You Know, Teach Them What They Need to Know "

That way the students see how Physics prepares them for their career, instead of being a course that is designed to " cull the herd! " All chapters relate to Medical Topics. Too many textbooks spent too much time, exposing students to non- Medical Physics, so the students just memorize the material. They feel that Physics is an Educational Hurdle to Master, which has limited value for a Pre-Med Candidate.

A3.1-03 - 4:55 p.m. | Contributed | Biophysics in the Undergraduate Curriculum*Presenting Author: Peter Nelson, Fisk University*

A new active-learning pedagogy is presented that includes computation as a central theme. The approach starts with the "marble game", a kinetic Monte Carlo simulation of diffusion. Students first learn how to play the game by hand and then implement it in Excel to discover that Fick's law of diffusion can be explained by random jumping between two boxes. In a guided-inquiry environment, students apply the same techniques to drug elimination, radioactive decay, osmosis, ligand binding, enzyme kinetics, and ion channel permeation. Students discover for themselves the consequences and significance of model assumptions by reading and interpreting graphs, and by comparing model predictions with real data using linear regression and non-linear least-squares fits. The pedagogical objective is for students to discover for themselves that science is an evidence-based endeavor with testable hypotheses that are supported by experiment.

Session A2.1: Frontiers in Planetary Science II Friday Jan. 7, 4:15–5:15 p.m.

Moderator: TBA Sponsor: Committee on Space Science and Astronomy

A2.1-01 - 4:15 p.m. | Invited | Mars, Lanka and Habitability: Serpentinization as a Thread of Life*Presenting Author: Suniti Karunatilake, Geology and Geophysics, Louisiana State University**Additional Author | Meththika Vithanage, Ecosphere Resilience Research Center, U. of Sri Jayewardenepura, Sri Lanka**Additional Author | Rohana Chandrajith, Department of Geology, U. of Peradeniya, Sri Lanka**Additional Author | Scott Perl, NASA-JPL, Caltech**Additional Author | Juan Lorenzo, Geology&Geophysics, LSU*

Additional Authors: Sanjeewa P.K. Malaviarachchi and Prasanna Lakshitha Dharmapriya, Department of Geology, U. of Peradeniya, Sri Lanka,

Serpentinization highlights the intersection of habitability and geology in comparative planetology. Its significance is enhanced for Mars from orbital nuclear spectroscopy evidence for more mafic crustal chemistry compared to Earth. This may also enable serpentinization to sequester crustal water, possibly complementing phyllosilicate minerals considered recently. However, despite numerous serpentine zones across Earth's continents, detailed analog studies are limited to a few formations such as the ophiolites in Oman. Meanwhile, autochthonous soils at Sri Lanka's serpentine zone provide the first laboratory evidence that perchlorates, found across in situ sites on Mars, can facilitate the release of biohazardous cations from soil into brines. The presence of variably developed soils across Sri Lanka's serpentine zone offers a planetary end-case reference for pedogenesis in serpentinites. Furthermore, several thermal springs near this zone can elucidate fluid chemistry from meteoric waters percolating through serpentinites, significant to paleo-Martian conditions when a surface hydrosphere may have existed.

Session A6.1: Integrating Computation in Labs at All Levels II Friday Jan. 7, 4:15–5:15 p.m.

Moderator: TBA Sponsor: Committee on Educational Technologies / Co-Sponsoring: Committee on Laboratories

A6.1-01 - 4:15 p.m. | Invited | Phys21 in 2021: Progress in Implementation

Presenting Author: Robert MacDuff, TRU-ED Inc

In October 2016 the Joint Task Force on Undergraduate Physics Programs issued its report, Phys21: Preparing Physics Students for 21st Century Careers. This effort by AAPT and APS provided guidance to physics departments that seek to foster the knowledge and skills their students need to be successful in a wide range of careers, which might include (but are not limited to) graduate education in physics and related fields. Since that time many departments have taken up the challenge to serve their students in this way, and follow-on activities of the professional societies have provided additional resources. I will describe some of these efforts, including the EPIC (Educating Physicists for Impactful Careers) report produced by the Pathways to Innovation & Physics Entrepreneurship: Launching Institutional Engagement (PIPELINE) project. I hope that learning about these activities will inspire more departments to take a piece of the PIE (Physics Innovation and Entrepreneurship).

A6.1-02 - 4:45 p.m. | Contributed | Physics Teachers Should Teach Machine Learning

Presenting Author: Donald Smith, Guilford College

Machine Learning is becoming ubiquitous in the realms of science, business, law enforcement, and even the arts. Many people don't realize how rooted in "physics thinking" the foundations of machine learning algorithms are, but physics teachers are well positioned to teach students to use these tools and how to understand their limitations. I have developed a three-week general education course on machine learning for non-scientists, and I adapted several activities for an introductory laboratory sequence in a course on Galaxies and Cosmology. I will report on the successes and challenges of these endeavors and make recommendations on how students can be prepared at multiple educational levels to engage with the opportunities and dangers these tools represent.

A6.1-03 - 4:55 p.m. | Contributed | A STEMcoding Data Science Curriculum

Presenting Author: Richelle Teeling-Smith, University of Mount Union

Additional Author | Chris Orban, The Ohio State University

Students, parents, and teachers are increasingly dissatisfied with the algebra to calculus high school math sequence and many see "data science" as a highly relevant subject that utilizes many of the same conceptual underpinnings in a computational context and think it could be a potential alternative. But, as of yet, there is no widespread agreement about what high school "data science" should cover. We are developing a physical science-informed high school data science course that will be useful in a variety of physics and astronomy courses. This course emphasizes the computational thinking and data processing tools indicative of data science, and includes hands-on direct measurement activities that are suitable for a physics classroom. We are excited to share our progress on this work which was recently funded by the American Institute of Physics Meggers Award.

A6.1-04 - 5:05 p.m. | Contributed | Computational Modeling in the Introductory University Physics Lab

Presenting Author: Ernest Behringer, Eastern Michigan University

The Department of Physics and Astronomy at Eastern Michigan University requires students who have chosen a physics major or minor to take a course introducing them to scientific computation. Because that course has evolved from introducing both spreadsheets and Python to focus solely on Python, there was an opportunity and need to incorporate computational modeling with spreadsheets in the laboratory portion of the calculus-based introductory mechanics course. Students now learn the Leapfrog method of numerical integration to computationally model falling with air resistance, the spin-down of a rotary motion sensor and magnetically damped fidget spinner, and the oscillations of spring-mass systems and physical pendula. We describe the content and sequencing of these labs and how these new labs are consistent with an increasing focus on student skill development.

Session A7.1: Lobby Physics and the Art of Demonstrations II Friday Jan. 7, 4:15–5:15 p.m.

Moderator: TBA Sponsor: Committee on Science Education for the Public / Co-Sponsoring: Committee on Apparatus

A7.1-01 - 4:15 p.m. | Contributed | Physics Demonstrations – From the Classroom to the Remote Landscape

Presenting Author: Monika Wood, University of Michigan

During the pandemic, the format of class instruction changed from in-person to entirely remote. What does a group that provides physics demonstrations to lecturers to supplement instruction do to continue to offer the same level of access to our catalog? We digitize! Working with instructors to identify their needs, we provided short videos of demonstrations performed in various ways. By using multiple cameras, professional editing software, strategic planning, and Youtube we have compiled a physics demo video library accessible to the world. Here is what we learned on our journey.

A7.1-02 - 4:25 p.m. | Contributed | Conservation of Energy with a Looping Hot Wheels® Track

Presenting Author: Amber Sierra, Arkansas Tech University

Additional Author | Jessica PC Young, Arkansas Tech University

We created a cheap but exciting lobby demonstration focusing on Conservation of Energy. We used a looped Hot Wheels® Track normally powered by batteries and replaced the batteries with a hand crank. The participants are asked to convert their chemical energy to electrical energy and observe the electrical energy being converted to mechanical energy. Then the participants are challenged to determine the minimum amount of hand crank that gives the car enough energy to fully loop the track. They are also asked what happens to the excess energy when they provide more than the minimum amount of energy the car needs to complete a loop. Participants can then compete with one another to determine who has the skills to produce the most consecutive loops.

Session: Modern Eddington Experiment: 2024 Friday Jan. 7, 4:15–5:15 p.m.

Moderator: Toby Dittrich Sponsor: Committee on Space Science and Astronomy

On April 8, 2024, another Great American Eclipse will cross the North American continent from central Mexico, through Texas and exit in New England. It will be a very long duration eclipse, 4.5 minutes, which is perfect for execution of the Modern Eddington Experiment (MEE). During the 2017 eclipse, students at Portland Community College (OR) collected 23 images of the eclipsed Sun with a total of 43 stars around it. From this data, they became the first physics students to have measured the curvature of space by determining the Einstein coefficient. This is a result of the use of modern relatively inexpensive (\$20k per station) telescope/camera combinations, a set of equipment that your school could obtain and join in the recreation with even better equipment and methods in 2024. Please participate in this session, where the project will be discussed, the equipment shown and explained, and the fabulous site in the central high desert of Mexico will be revealed. The goal of this effort is to make the MEE a regular advanced lab experiment for many schools on into the distant future. This educational exchange program with a Mexican college will be a wonderful experience for your students, an experience hopefully repeated indefinitely into the future by your school and others.

Session A10.1: Physics of the Body and Sports Friday Jan. 7, 4:15–5:15 p.m.

Moderator: Dan Liu Sponsor: Committee on Research in Physics Education

A10.1-01 - 4:15 p.m. | Invited | Interactive Simulations of the Human Body

Presenting Author: Dan Liu

This presentation covers the ongoing effort to develop a collection of interactive Simulations of the human body. It is an open-source inquiry learning material on the subject of key concepts in equilibrium not only for the students majoring in health sciences, but also for physics students in general. Students can practice and apply physics to calculate the forces on muscles and joints of different group of people under various situations. The simulations can be implemented as an inquiry-based virtual lab or an exploration assignment. Besides enhancing the understanding of lecture materials related to equilibrium, the simulations can scaffold students to explore new biomechanics projects.

A10.1-02 - 4:45 p.m. | Invited | A Physics-driven Study of Dominant Space in Soccer

Presenting Author: Gregory DeCamillis, University of Central Florida Physics Department

Additional Author | Costas Efthimiou, University of Central Florida Physics Department

Additional Author | Indranil Ghosh, Massey University School of Fundamental Sciences

In [1], a physics-driven kinematical method was introduced to produce an improved model for dominant regions in soccer. Contrary to other similar attempts, the model maintains the deterministic nature of the Voronoi diagram. Remaining faithful to the deterministic approach, we extend the work of [1] by the introduction of (a) an asymmetric influence of the players in their surrounding area, (b) the frictional forces to the players' motion, and (c) the simultaneous combination of both effects. For the frictional force, we include a portion from air resistance [2] proportional to v^2 , where v is the velocity of the player, and a portion from internal mechanisms, at the suggestion of biokinematics [3], proportional to v . We establish exact analytical solutions of the dominant areas of the pitch by introducing a few reasonable simplifying assumptions. Given these solutions the new Voronoi diagrams are drawn for the publicly available data by Metrica Sports.

[1] C. J. Efthimiou, The Voronoi Diagram in Soccer: a theoretical study to measure dominance space, <https://arxiv.org/abs/2107.05714>.

[2] A. V. Hill, The Air-Resistance to a Runner, Proc. R. Soc., B102 (1927), pp. 380-385, <https://doi.org/10.1098/rspb.1928.0012>.

[3] K. Furusawa, V. Hill, and J. L. Parkinson, The dynamics of "sprint" running, Proc. R. Soc., B102 (1927), pp. 29-42, <https://doi.org/10.1098/rspb.1927.0035>.

Session A4.1: Quantum Education at the K-12 Level II Friday Jan. 7, 4:15–5:15 p.m. Moderator: Chandralekha Singh

Sponsor: Committee on Science Education for the Public / Co-Sponsoring: Committee on Physics in High Schools

A4.1-01 - 4:15 p.m. | Invited | Building Quantum Computing Intuition through Visuals, Activities, and Games

Presenting Author: Diana Franklin, University of Chicago / Computer Science

Quantum computing is traditionally taught with a mathematical approach, featuring linear algebra and an emphasis on proofs, two subjects not prominent in K-12 education. In this talk, we present our approach of taking QIS key concepts such as superposition, entanglement, measurement, and decoherence, and applying them to familiar situations such as tasting jelly bellies, guessing what card was flipped, and playing Connect 4. Our goal is to understand how young learners conceptualize these concepts in real-world settings, how those conceptions align and do not align with their application to quantum computing, and design instruction that both builds on their existing knowledge and bridges to quantum computing. The end goal is to delay math as much as possible in order to allow early introductions of the concepts.

A4.1-02 - 4:45 p.m. | Invited | Re-engineering Physics Curriculum

Presenting Author: Karen Matsler, UT Arlington

The National Quantum Initiative was designed to support the development of quantum information science (QIS) workforce pipelines. These national efforts are vital to our national industrial growth and security in an increasingly competitive global quantum landscape, but there are many challenges. These challenges include the need to re-engineer current standards and curriculum in physics. The Quantum for All project is focusing on re-engineering STEM curriculum in order to provide QIS content and age appropriate resources for high school teachers to use in the classroom. This presentation will highlight the methodology being used to re-engineer physics curriculum as well as the challenges and successes of developing effective QIS methodologies for all K-12 students, the future workforce.

A8.1-01 - 4:15 p.m. | Invited | Waving Arms and Skits in Quantum Mechanics

Presenting Author: Kelby Hahn, Oregon State University

Additional Author | Elizabeth Gire, Oregon State University

In the Paradigms in Physics curriculum at Oregon State University, we teach a series of spins-first quantum mechanics courses that incorporate various types of active-engagement pedagogies. In this talk, I will highlight the kinesthetic activities used in our junior-level Quantum Fundamentals course and their role in the broader context of our quantum mechanics courses. These kinesthetic activities include the Arms Activities where pairs of students use their left arms to embody quantum mechanical spin states and the Quantum Measurement Skit where the class acts out the measurement of quantum states. In addition to presenting the activities, I will discuss results from interviews with students about their understanding and experience with Arms.

A8.1-02 - 4:45 p.m. | Invited | Bringing Quantum Information Science to Students at Predominately Undergraduate Institutions

Presenting Author: Justin Perron, California Sate University San Marcos, Department of Physics

Additional Author | Edward Price, Department of Physics, California Sate University San Marcos

Additional Author | Charles DeLeone, Department of Physics, California Sate University San Marcos

Additional Author | Shahed Sharif, Department of Mathematics, California Sate University San Marcos

Additional Author | Tom Carter, Department of Computer Science, California State University Stanislaus

Currently, the majority of undergraduate education and workforce training in quantum information science and technology (QIST) is occurring at doctoral-granting institutions. To meet the anticipated quantum workforce needs and to ensure the workforce is demographically representative and inclusive to all communities, the United States must expand on these efforts and incorporate QIST into the curriculum at the nation's predominantly undergraduate institutions (PUIs). In June 2021 roughly 90 faculty from PUIs participated in a workshop aimed at facilitating this expansion. After panels describing industry needs, current education efforts, and best practices, workshop participants identified challenges they would face when incorporating QIST into curriculum at their institutions. Discussions then focused on strategies and solutions for these challenges. This talk will summarize these discussions including programmatic approaches, gaining institutional support, course content and design, and inclusive practices. I will also discuss ongoing efforts to bring QIST into the curriculum at predominantly undergraduate institutions.

A8.1-03 - 5:15 p.m. | Contributed | Quantum Party! Incorporating Quantum Mechanics Rules into a Board Game*

Presenting Author: Matthew Bellis, Siena College

Additional Author | Abigail G Huffman, Siena College

Additional Author | Germaine Gatewood, Siena College

We developed a board game that incorporates the rules of quantum mechanics into the game play, Quantum Party!. The goal was to create a fun and effective pedagogical instrument that could be used at the high-school or introductory college level, or even sold to the general public. We now have a professional-looking game that can be purchased online by anyone. It comes with multiple tools (dice, spinner) that replicate the science behind 4 classic quantum mechanics experiments/observations, a well as a manual that teaches both the game rules and the science behind the game, and of course, cats! Since its creation, we have run workshops with high-school teachers to brainstorm on how this can be used in the classroom. In this talk, I will give a summary of this process and where we see this going in the future.

*This project was supported in part by a grant from the AAPT Bauder Fund in 2019.

This session is the primary opportunity for members of the PER graduate students 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!

Saturday, Jan. 8

– Plenary II - Matt Greenhouse, James Webb Space Telescope Program GSFC Observational Cosmology Laboratory, 10–11 a.m.

– Exhibitor Meetups, 11 a.m.–12 p.m.

Session A1.1.1: Preparing Students for 21st Century Careers Saturday, Jan. 8, 12–1 p.m. Moderator: Troy Messina
Sponsor: Committee on Laboratories

A1.1.1-01 - 12:00 p.m. | Invited | The Mathematics of Quantities (make math, make sense)

Presenting Author: Laurie McNeil, University of North Carolina at Chapel Hill

Interestingly enough, if you stop and think about it, science makes no sense from an observational perspective. Consider $F = ma$, what does the “=” symbol reference? Or for that matter what does it mean to multiply mass with acceleration? $K.E. = 1/2 mv^2$, raises more questions: what does v^2 look like; or why does K.E. only equal half of mv^2 ? If equations “described” exactly what is taking place not experimentally but experientially, learning would be vastly easier. In other words, equations can be expressed in a form where they are the means of describing “this” in terms of “that” which requires a “relationship” between the “this” and “that”. Expressed in this way, the laws of nature take on a completely different meanings.

A1.1.1-02 - 12:30 p.m. | Invited | Shifting Culture to Support Physics Innovation and Entrepreneurship Curriculum Implementation

Presenting Author: Anne Leak, High Point University

Recommendations in the Phys21 and EPIC reports emphasize the need for undergraduate physics programs to prepare students for a wide range of careers. Yet, following these recommendations requires a fundamental shift in both physics curricular experiences and cultural values. The Pathways to Innovation & Physics Entrepreneurship: Launching Institutional Engagement (PIPELINE) project has developed several curricular experiences (including new courses, lessons, makerspaces, and lab activities etc.) and explored the existing cultural landscape (including faculty and student perceptions and values of physics innovation and entrepreneurship skills). Many students lack awareness of their own potential for physics-related careers and feel that skills employers find valuable (e.g., leadership and business skills) are not relevant to physics. To expand the careers physics majors can and feel they can pursue, we need to shift students’ perceptions and align what counts as physics in department cultures with the Phys21 recommendations.

Session A10.2.1: Apparatus @Home Saturday, Jan. 8, 12–1 p.m. Moderator: Stephen Irons
Sponsor: Committee on Apparatus

A10.2.1-01 - 12:00 p.m. | Contributed | Biomechanics Lab Activities with Interactive Worksheets

Presenting Author: Nancy Beverly, Mercy College

Curricular materials where students explore human biomechanics, including activities with their own bodies, were developed for an introductory physics course that serves exercise science and pre-physical therapy students. In the lab activities, students use force plates, goniometers, and video analysis to analyze the biomechanics of their own bodies. During the recent period of remote learning, interactive worksheets with previous student data were developed for students to practice data analysis, graphical interpretation, and diagrammatic skills with emphasis on conceptual understanding. They involved digital click and drag features. These interactive worksheets are now used as templates for use with students’ own data and pictures now that we are back in the classroom. These interactive worksheets are also being modified for use in our Physics of the Human Body course.

A10.2.1-02 - 12:10 p.m. | Contributed | The Simple Slinky Wave Speed

Presenting Author: James Vesenka, University of New England

Additional Author | Mackenzie P Bird, University of New England

Additional Author | Nathan P Carrier, University of New England

Additional Author | Christopher P Weiss, University of New England

At-home wave mechanics are demonstrated with the inexpensive iOLab sensor system and a slinky. A surprising result is demonstrated by measuring the standing wave speed of a slinky. The wave speed does not appear to increase with Hookean tension on the slinky! The reason is the slinky’s linear density also changes in direct proportion with its stretched length. This counterintuitive result can be easily explained conceptually and mathematically, providing students with a richer understanding of wave mechanics [Huggins].* Most importantly this experiment is easily accomplished at home, even without the iOLab, using a ruler and kitchen scale. The results of this activity from an introductory physics UNE Spring 2021 virtual online course student presentation are provided.

*Elisha Huggins, Speed of Wave Pulses in Hooke’s Law Media, *The Physics Teacher* **46**, 142 (2008); <https://doi.org/10.1119/1.2840977>

A10.2.1-04 - 12:30 p.m. | Contributed | Determining Density with Water, a Ruler, Floss, and Some Nickels

Presenting Author: Paul Schmelzenbach, Point Loma Nazarene University

This pandemic-motivated lab was created to explore ideas of buoyancy, static equilibrium, and experimental uncertainty for the introductory physics student. The unknown density of an object was determined by weighing it in and out of water. A make-shift scale was created using a ruler and nickels. Particular attention was paid to uncertainties of measurements with the propagation of error carried out using Python.

A10.2.1-05 - 12:40 p.m. | Contributed | The Mechanical Rotating Saddle Trap in High School Physics Education

Presenting Author: Sebastian Kilde Löfgren, Department of Physics, University of Gothenburg

Additional Author | Jonas Enger, Department of Physics, University of Gothenburg

Additional Author | Jonathan Weidow, Department of Physics, Chalmers University of Technology

Based on a mechanical analog to a particle trapping technique, the Paul trap, a lab has been developed to train scientific thinking and experimental problem-solving. It also works to illustrate an important concept in many areas of modern physics. The mechanical trap will together with a simulation give students an introduction to the concept of particle trapping. The lab has been developed to contribute to the ever-important task of making high school physics more interesting, to get more students pursuing careers in STEM, and increasing scientific literacy in the public. Using a design-based approach to developing the lab, its effectiveness on student learning and interest is probed using qualitative and quantitative methods, and initial findings from the study will be presented.

A10.2.1-06 - 12:50 p.m. | Contributed | Sums of Arbitrary Dice for Physics Students

Presenting Author: Duncan Carlsmith, University of Wisconsin-Madison

The study of dice introduces physics students to scientific ways of knowing, chaos, and probability and statistics. This talk shows how to calculate the probability distribution for the sum of any combination of dice with any numbers of faces, weights, and positive or negative integral face values, using generating functions and math accessible to a high school student. Relevant computer code is available which makes such calculations effortless.

The first part of this talk presents an invitation to the study of chaos in the impact mechanics of tumbling dice.

Session A2.1.1: Astronomy Papers Saturday, Jan. 8, 12–1 p.m. Moderator: TBA

Sponsor: Committee on Space Science and Astronomy

A2.1.1-02 - 12:10 p.m. | Contributed | An E&M Theory for Inertial Mass in Newton's Second Law

Presenting Author: Lishang Rao, Future Start & Candle Light Non-Profitable

This is an E&M theory to explain the inertial mass in Newton's second law. The inertial mass and attractive mass had been the same in Newton's second law and his Universal Gravitation Law; and their connections to other physical concepts had been mysterious. In this presentation, the inertial mass and attractive mass are not two mechanical concepts, rather, they have an E&M basis.

A2.1.1-03 - 12:20 p.m. | Contributed | Vacuum Field Fluctuations May Cause Differentiation of Charge Coupling Constants

Presenting Author: Lishang Rao, Future Start & Candle Light Non-Profitable

I proposed a theory previously that different charge coupling constants between positive and negative charges in Coulomb's law may result in an attractive force between two electrically neutral objects. This presentation provides a theoretical evidence that the vacuum field fluctuations may cause such differentiation of charge coupling constants, in the way that favors the attractive net force between two electrically neutral objects.

A2.1.1-04 - 12:30 p.m. | Contributed | Deserving a Nobel? The Harvard Computers and Other Neglected Pioneers

Presenting Author: Richard Gelderman, Western Kentucky University

“Should a Nobel prize have been awarded to Annie Jump Cannon, Cecilia Payne Gaposchkin, Henrietta Leavitt, Vera Rubin, Margaret Geller, or Jocelyn Bell Burnell? Locate, read, and cite at least three separate sources to justify your response.” This assignment can be used at the beginning of a term to spark interest before students get daunted by their academic load, or can come at the end of the term as a capstone project. Providing a list makes the assignment appear more straightforward. However, since the top hits on the Internet pull up mostly female astronomers, to ask students to argue on behalf of any astronomer overlooked by the Nobel committee produces similar results while preventing any complaints that a social agenda is being pushed.

A2.1.1-05 - 12:40 p.m. | Contributed | Investigating the Impacts of a Cultural Cosmology Project

Presenting Author: Janelle Bailey, Temple University

Additional Author | Kim Coble, San Francisco State University

Providing students the opportunity to explore cultural aspects of cosmology (such as those of Indigenous, non-Western, or marginalized groups) can be a powerful way to foster safe spaces within astronomy. We are investigating the impacts of such a project, used in an upper-division course but adaptable to introductory astronomy. Students' written reflections and oral interviews suggest that their interest in cosmology specifically and astronomy in general was strengthened by studying and presenting on the cosmology of a non-dominant culture or narrative. They reported surprise in the number of ways where the cosmological beliefs of their selected culture aligned with current science, within the limitations of available technology of the time. Students also reported that engaging with the projects made them feel like the astronomical community would be welcoming of them, even if they are not from the majority demographic, and that it supported goals of continued astronomical learning.

A2.1.1-06 - 12:45 p.m. | Contributed | Maria Mitchell (1818-1889), Astronomer and Pioneer of Women's Education

Presenting Author: William Palmer, Curtin University

Maria Mitchell was born on 1st August 1818 in Nantucket, MA, to William and Lydia Mitchell. She was the third of 10 children in the Quaker family who strongly believed in the education of girls. Her father was an astronomer and teacher and influenced her love of astronomy. She completed her formal education when she was 16 years old. In 1836, she obtained a position as librarian at the Nantucket Athenaeum, which was a position she held for 20 years. During the day, she worked at the Athenaeum, and she studied the stars during the night with her father. In 1847, she discovered a comet, known as the 'Miss Mitchell comet,' which led to her becoming well-known in scientific circles. She was recruited by Vassar College to join the staff and was influential in the lives of many women scientists. She died in 1889, soon after retiring from Vassar.

Session B 1: Engage Students, Meet Standards, and Contemporary Physics being Incorporated into Classical Physics

Classes in MS and HS Saturday, Jan. 8, 12–1 p.m. Moderator: Marla Glover Sponsor: Committee on Teacher Preparation

B1-02 - 12:10 p.m. | Contributed | Preparing Students and Teachers for the “Second Quantum Revolution”

Presenting Author: Mark Hannum, AAPT

Presenting Author | Kiera Peltz, Qubit by Qubit/

Quantum technologies, such as quantum computing, have attracted significant attention in recent years from industry leaders, academia, and national governments, but there are still few opportunities to learn about quantum at the K-12 level today. In this session, two leading quantum education organizations, the American Association of Physics Teachers and Qubit by Qubit, a nonprofit quantum education organization, will discuss the lessons they've learned introducing teachers and students to Quantum Information Science and Engineering (QISE). This session aims to equip attendees with a clear understanding of why quantum education is important at the K-12 level; an understanding of best practices in quantum education; and ideas for how physics teachers can begin incorporating QISE into their curriculum.

B1-03 - 12:20 p.m. | Contributed | Integrating Physics with Literature and Projects: Pedagogy for Nontraditional Students

Presenting Author: Philomena Agu, Barbara Jordan Career Center

To make physics relevant to non-traditional students and English language learners, I introduced children's literature books and other reading materials into my class in the Fall semester. “The Boy Who Harnessed the Wind”, “Ricky the Rock that Couldn't Roll”, “Pheasant and Kingfisher”, “Never Play Music Right Next to The Zoo”, and “Hurricane Ida” were some pieces of literature my students read. The students could relate illustrations and text to physics contents, including electricity, projectiles, mechanical waves, motion and force, and observe physics in their everyday experience. Mixed with projects, students find my class exciting, show interest in the course and are motivated to learn. Moreover, this pedagogy effectively replaced pandemic screen learning, where over fifty percent of my class failed. My students use project grades to offset a failing traditional test in this face-to-face teaching since both have the same weight. Currently, most of my students are passing.

B1-04 - 12:40 p.m. | Contributed | Smartphone Applications as Part of an Introductory Lab Reform Project

Presenting Author: Andy Gavrin, Indiana Univ. Purdue Univ. Indianapolis (IUPUI)

We have made the use of smartphone applications a centerpiece of our efforts to reform the introductory labs in both our calculus-based and algebra-based classes. Students use smartphone applications in experiments completed in the lab (Bluetooth paired with sensors) and at home (using the native sensors in the phone). This has allowed us to reduce crowding in the lab, to give students a greater sense of agency in the experiments that they do, and to incorporate more sophisticated “data handling” in the learning goals for the labs. This talk will give an overview of the project and highlight several examples of labs in which smartphones play a prominent role.

Session A4.1.1: High School Saturday, Jan. 8, 12–1 p.m. Moderator: TBA

Sponsor: Committee on Physics in High Schools

A4.1.1-03 - 12:20 p.m. | Contributed | “Shedding Some Light” Spectroscopy Investigation

Presenting Author: Angela Douglass, Ouachita Baptist University

Presenting Author | Susan Allison, Dawson Educational Cooperative

Electromagnetic waves, or light, penetrate many topics in physics, chemistry, engineering, and biology. They are the foundation for many applications such as cell phones, GPS, medical equipment and procedures, 3D movies, astronomy, and so much more! In this high school lesson, we use the new Netflix logo to lead high school students through an inquiry-based experiment on light and spectroscopy. Students use diffraction glasses and multiple gas emission tubes to observe the unique spectra of gases. They record the colors they see in each element and estimate the wavelength and corresponding frequency of each spectral line. Students then are guided to discover the relationship between the frequency and wavelength of light. In addition, students learn about energy of light, the scientists who discovered spectra, and applications of spectroscopy today. In this presentation, we will share the developed lesson and the learning progress of several classes from local schools.

A4.1.1-05 - 12:40 p.m. | Contributed | Case Studies: High School Seniors Applying to College Engineering Programs

Presenting Author: Devyn Shafer, University of Illinois at Urbana-Champaign

Additional Author | Tim Stelzer, University of Illinois at Urbana-Champaign

Who are the high school students applying to college engineering programs? In this talk, we will share some preliminary findings from interviews with aspiring engineers. How do they view themselves? What is important to them? How do they manage their schoolwork? How do they make decisions, and who influences them? We will share some of the first data collected in a two-year longitudinal study of student transitions from high school to college engineering programs with long-term goals of identifying ways that high schools and colleges can better support engineering students. For now, we are starting to get to know the students and look forward to sharing a snapshot of their lives with you.

Session B2.1: Introductory Labs/Apparatus Saturday, Jan. 8, 12–1 p.m. Moderator: TBA

Sponsor: Committee on Apparatus / Co-Sponsoring: Committee on Laboratories

B2.1-01 - 12:00 p.m. | Contributed | Curve-fitting with Model Testing Using Chi-Square Minimization in Excel

Presenting Author: Carey Witkov, Embry-Riddle Worldwide

Ordinary least squares (OLS), developed over two centuries ago, is still the most common curve-fitting method used in introductory physics labs. OLS offers best-fit parameter estimates, but best-fits may not be good fits. Moreover, OLS best fits may be biased (the outlier problem) where anomalous data is overweighted. Chi-squared minimization (CSM) provides both parameter estimation and model testing in one consistent methodology. CSM can be shown to be the optimal method of parameter estimation with Gaussian distributed uncertainties and solves the outlier problem by weighting data inversely with their uncertainties. However, more than being just a weighted least squares (WLS) method, CSM also provides two easy-to-apply criteria for model testing. CSM is a computation-intensive method whose gold-standard implementation in particle physics software is difficult for introductory physics students to use. A simplified form of CSM is implemented in an Excel spreadsheet, making this valuable tool accessible to introductory physics students.

B2.1-02 - 12:10 p.m. | Contributed | The Impact Shock of Falling Packages with Finite Cushioning Layer

Presenting Author: Wojciech Walecki, Mater Academy, Doral College, Miami Dade College

We present a simple, safe, freshman college or high school student lab experiment applying 1D kinematic equations (1DKE) to the important problem of packaging fragile goods. Using 1DKEs, we modeled the motion of a packaged object falling on the floor. We split the motion to two phases: the free-fall phase from initial height H with acceleration $g = 9.8$ m/s², and the landing phase with a constant acceleration a . We assumed that the cushioning layer underwent total compression from the initial thickness D to zero. We demonstrated that $|a| > (H/D) * g$. Students experimentally validated this inequality by drop tests of the packaged wooden cubes with attached resettable shock sensors [1]. As an extension, we discuss various models of cushioning including weightless springs and discrete spring-mass chains. This is an inexpensive experiment: the cost of the entire reusable set up for the team of three students is below \$10.

1. https://www.uline.com/BL_1051/Drop-N-Tell

B2.1-03 - 12:20 p.m. | Contributed | Investigating Entropy and Disorder with Hands-On Models

Presenting Author: Ryan Rogers

Entropy is taught at all levels of physics. However, many students have a poor understanding of entropy, often conflated with disorder. Understanding the quantitative definition of entropy-- a function of the accessible energy states-- provides a more functional education. This demonstration explains entropy in a macroscopic and theoretically sound manner, using hand-held containers and simple objects to model entropically-driven processes. A spontaneous entropy increase causes increased order, consistent with more available energy states, but contradicting the “entropy is disorder” paradigm. This talk describes the demo’s thermodynamic basis and simple calculations that validate viewer observations. The demo provides memorable examples on which to build a sound understanding of entropy, meanwhile exposing failures of the disorder paradigm. Students with a proper concept of entropy are better equipped not just to answer pedagogical questions, but also to discern fictitious paradoxes of the disorder paradigm from genuine implications of the second law of thermodynamics.

B2.1-04 - 12:30 p.m. | Contributed | New Astronomy Laboratory Simulations with Python

Presenting Author: M. Virginia McSwain, Lehigh University

Project CLEA at Gettysburg College has long been a popular package of simulations for introductory astronomy labs. Unfortunately, CLEA is no longer developing new software, and the existing software can be difficult to install with newer versions of Microsoft Windows or other operating systems. I have developed three new open source, Python-based simulations that were inspired by their CLEA counterparts and can be easily installed on a broader variety of modern computers. I will describe their features and how I have used them in my lab courses. They are available for public download in GitHub, and I encourage others to adopt them for their own courses.

B2.1-05 - 12:40 p.m. | Contributed | Fostering Design and Communication Skills by Building a Scientific Apparatus

Presenting Author: Micol Alemani, Physics and Astronomy Department, University of Potsdam

Additional Author | Markus Guehr, Physics and Astronomy Department, University of Potsdam

Traditional physics laboratory courses featuring pre-optimized experiments do not allow for authentic scientific experiences. There is very little space for the design and optimization of measurement procedures or the experimental apparatus. Recent efforts in the physics education research community have been targeting this particular problem in laboratory classes. We present an example of a student project in our physics laboratory course to offer such an authentic experience. In this four-day project, students form teams to design and construct a scientific apparatus capable of distinguishing different beverages using optical spectroscopy. The students need to devise a measurement strategy, design and build an optical spectrometer using 3d-printed parts to accomplish this goal. They then optimize the apparatus and measurements iteratively. In this talk, we present the results and particular structure of the project, as well as the scaffolding and rubrics we introduced to guide students during their work.

B2.1-06 - 12:50 p.m. | Contributed | A Student Designed Lab to Test Newton's 2nd Law

Presenting Author: Richard Guarino, Southern Methodist University

Additional Author | Jingbo Ye, Southern Methodist University

Students explore Kinematics using a Pasco smart cart on an inclined track. They discover that their calculations and measurements don't agree but can be brought into agreement by adding a small constant to the average acceleration. A later lab uses the smart cart on a level track to analyze Newton's 1st law. Again they see that the speed is not constant but is slowing. A third lab looks at the physics of a cart in equilibrium on an inclined plane for different angles. Tension and normal force are measured and compared to calculated values. After performing these labs, the students are asked to design a lab to test Newton's 2nd law including the instruments used, the procedure and analysis. This exercise broadens the student's physical intuition and exercises their understanding of the experimental method of having a model, predicting results and comparing to measurements to validate the model.

Session B8: Misinterpretations of Quantum Mechanics in the Classroom Saturday, Jan. 8, 12–1 p.m.

Moderator: Andrew Mason

Sponsor: Committee on History & Philosophy of Physics

B8-01-12:00 p.m. | Invited | Using IBM Quantum Computers to Explore Interpretations of Quantum Mechanics

Presenting Author: Jarrett Lancaster, High Point University

Teaching students about various interpretations of quantum mechanics can be difficult without hands-on activities that force students to confront tangible experimental results. IBM quantum computers provide a freely accessible experimental environment in which students can perform classic quantum experiments on actual, cloud-based, quantum hardware. I will discuss how incorporating this technology into an undergraduate quantum mechanics course has provided new opportunities for discussing various interpretations of quantum mechanics. Additionally, I will describe how this experimental approach reveals common misconceptions concerning the measurement process and the nature of quantum states.

*I acknowledge the use of IBM Quantum services for this work. The views expressed are those of the author, and do not reflect the official policy or position of IBM or the IBM Quantum team. Additionally, I acknowledge the access to advanced services provided by the IBM Quantum Educators Program.

B8-02-12:30 p.m. | Invited | Putting Probabilities First in Teaching Quantum Mechanics

Presenting Author: Michel Janssen, University of Minnesota

I will present a course introducing quantum mechanics to college students from both STEM and humanities fields. The course is based on material in "Understanding Quantum Raffles" (Janas, Cuffaro and Janssen 2021). With the help of techniques in Bananaworld: Quantum Mechanics for Primates (Bub 2016), students analyze correlations allowed classically and quantum-mechanically in an EPR-Bell-type setup due to Mermin. Noting that the quantum correlations can be parametrized by the cosines of the angles between the detectors in this setup, the students are then led to the Born rule for probabilities in quantum mechanics. The idea is to introduce the basic formalism of quantum mechanics as an extension of ordinary probability theory. In line with modern information-theoretic interpretations of quantum mechanics, this basic formalism is presented as a new operating system on which many different applications can be written, ranging from spectroscopy to quantum computing.

Session B3: Other Papers Saturday, Jan. 8, 12–1 p.m.

Moderator: TBA

Sponsor: AAPT

B3-02 - 12:00 p.m. | Contributed | Supporting Graduate Students Through Opportunities in Physics Public Engagement Activities

Presenting Author: Bryan Stanley, Michigan State University

Additional Author | Kathleen Hinko, Michigan State University

Women and Minorities in the Physical Sciences (WaMPS) is a graduate student organization housed in the department of physics and astronomy at Michigan State University. WaMPS is a student-led organization encouraging women and minorities to pursue the physical sciences and supporting those who are already members of the physical science community. WaMPS outreach and public engagement includes school visits, public presentations, podcasting, and collaborations with community partners and members in other academic fields. By volunteering and participating in public engagement activities, students can build connections with peers and faculty, connect their formal learning to the real world, feel more connected to their field, and have opportunities to share their own experiences with others. In this talk, we focus on the experiences of graduate students who have participated and contributed in the WaMPS public engagement activities and the intersections with their career goals and aspirations.

B3-03 - 12:10 p.m. | Contributed | Development of Science Class in a Blended Learning Environment

Presenting Author: Taegyong Lee, Korea National University of Education / Kuksabong middle school

Additional Author | Nam-hwa Kang, Korea National University of Education

In the recent global pandemic, the educational environment of learners is rapidly changing to a blended learning environment, and the importance of cultivating students' digital literacy competency is also being emphasized. Meanwhile, information processing and decision-making ability, one of the main scientific skills that future generations should learn, can contribute to develop students' digital literacies in five areas: information search and information selection, information production, information evaluation, exploring alternatives, information-based value judgment. It is necessary to study the field application plan considering the current educational conditions to enhance students' information processing and decision-making ability. In this background, this research is about the development of middle school science class for developing scientific communication competency using digital tools.

B3-04 - 12:20 p.m. | Contributed | Experiences/Results of Bringing Undergraduates to AAPT Meetings

Presenting Author: Cindy Schwarz, Vassar College

Since 2017, I have brought over 40 undergraduate Vassar College students to AAPT meetings. One meeting was in person and the rest were virtual. Many students presented papers (either with me or on their own) and so much came out of the experiences for all of them. We are finishing an intensive course in the Fall of 2021 on the recent virtual meetings and I will show some of the work done in that course. I will also discuss the preparation I had to do to get them ready for the best experience as most had never attended a meeting. I will discuss documents created on best practices for faculty and students, and impacts on student career choices. Even those who will not choose teaching, they learned so much about learning and the dedication of great teachers. Student videos will be shown.

B3-05 - 12:30 p.m. | Contributed | Environmental Computing and Community Engagement in STEM education: Sustainable Relationships.

Presenting Author: Morewell Gasseller, Xavier University of Louisiana

Additional Author | David Brooks, IESRE

Additional Author | Timothy Laude, Xavier University of Louisiana

Additional Author | Kennedy Jeffrey, Xavier University of Louisiana

Additional Author | Hiba Abdelaziz, Xavier University of Louisiana

Xavier University of Louisiana, in collaboration with the Institute of Earth Science Research and Education (IESRE) run the ECoSTEM project. This project aims to improve the quality of undergraduate STEM education by introducing a computational, community-oriented component into STEM programs at Xavier University. Specifically, undergraduate students develop microcontroller-based systems for collecting airborne particulate data. They work with public school teachers (and their students) and Louisiana Department of Environmental Quality (LDEQ) officers to deploy the sensors at locations around New Orleans and to analyze the resulting data. Airborne particulates are often the pollutant of greatest concern in minority and other underserved communities. This project provide undergraduates at Xavier and the local teachers (and their students) with learning experiences that are relevant to them and their communities. ECoSTEM uses a tiered mentoring system in which the project team members mentor undergraduates, who in turn work with public school teachers and their students.

B3-06 - 12:40 p.m. | Contributed | Floating and Falling: 3rd-grader's Depictions of Forces in Wind Columns

Presenting Author: Devon Christman, University of California Santa Barbara

Additional Author | Alexandria Muller, University of California Santa Barbara

With the introduction of the Next Generation Science Standards (NGSS State Lead, 2013), physics and engineering are taking on a more prominent role in K-12 science instruction. To help teachers bring physics and engineering into their classrooms we partnered with a local hands-on science museum to create a series of activities that combine classroom learning with a fieldtrip experience to the museum. These activities aim to meet the NGSS physics standards in a way that is both fun and accessible for students of all grade levels. One such activity involves students building a structure designed to hover in a wind column at the museum. In this study we examine how 3rd grade students predict the forces acting in the wind column will affect the motion of their structure using both written words and pictorial models.

Session B4: PER: Assessment, Grading and Feedback

Saturday, Jan. 8, 12–1 p.m.

Moderator: TBA

Sponsor: Committee on Research in Physics Education

B4-01 - 12:00 p.m. | Contributed | Force Concept Inventory: Factor Structure Measurement Invariance Across Genders

Presenting Author: Philip Eaton, Stockton University

The dependence of the Force Concept Inventory (FCI) on student gender has been investigated in many research articles. For example, the factor structure of the FCI has been examined by separating male and female data, applying exploratory factor analysis and/or network analysis, and comparing the results. Unfortunately, both techniques are exploratory in nature and as a result are distinctly sample dependent. In this presentation the results of a measurement invariance analysis using confirmatory factor analysis will be presented. For the sample used, this analysis found male and female separated data (only self-identified binary genders were used due to limited data) fit the Eaton and Willoughby Modified 5-factor model of the FCI with strict measurement invariance. This suggests observed differences in performance between the genders are likely not a result of the gender groups interacting with different factor structures of the FCI. Similar analyses should be done to corroborate these results.

B4-03 - 12:10 p.m. | Contributed | Development of a Likert-style Assessment to Assess Learning Assistants PCK-Q

Presenting Author: Beth Thacker, Texas Tech University

Additional Author | Stephanie Hart, Texas Tech University

Additional Author | Kyle Wipfli, Texas Tech University

Additional Author | Jianlan Wang, Texas Tech University

We report on the development of a Likert-style assessment instrument designed to analyze pedagogical content knowledge of learning assistants (LAs) in the context of questioning (PCK-Q). After a rigorous process of analyzing and coding classroom videos and writing, testing and validating a free-response (FR) written assessment instrument, we focused on developing a Likert-style version of the instrument. The Likert-style version assesses an LAs ability to evaluate other LA's PCK-Q and has the advantage of machine scoring. We are still in the process of validating the Likert-style questions. Both instruments, FR or Likert-style, could be used as a pre- and a post-test at the beginning and end of the semester to assess LA's PCK-Q or parts of either instrument (individual questions) could be used to help with weekly lab (LA training) preparation. We report on the development of the Likert-style instrument. Funded by NSF IUSE grant 1838339.

B4-04 - 12:20 p.m. | Contributed | Scalable, Written Homework with Metacognitive Student Outcomes

Presenting Author: Laura Tucker, University of California-Irvine

Additional Author | Jerry Liu, University of California-Irvine

Additional Author | Alphonse Do, University of California-Irvine

Homework lets students practice the problem-solving process. The focus on process, rather than final answer, is particularly important. Unfortunately, many online homework systems, and some traditional pencil-and-paper strategies, grade based on the correct answer rather than students' written thought process. This can shift student focus away from the process. We have scaled a homework structure that emphasizes the problem-solving process and metacognitive reflection. Students are required to follow a problem-solving format developed previously, which has been shown to increase student metacognition.* In our procedure, students self-grade the completeness of their homework, and instructors perform a specific spot-check to increase student accountability. The spot-check takes minimal instructor time to administer and therefore can be scaled to large courses. Additionally, this homework structure shows high student satisfaction by the end of the term.

B4-05 - 12:30 p.m. | Contributed | Students' Reflections About an Ethical Dilemma in Physics

Presenting Author: Alexander Vasquez

Additional Author | Ciana Pike, Texas State University

Additional Author | Alice Olmstead, Texas State University

Additional Author | Brianne Gutmann, Texas State University

Additional Author | Daniel Barringer, Texas State University

It is important for physics students to develop ethics knowledge, yet this is rarely taught in undergraduate physics classes. We are addressing this limitation in an ethics unit for an observational astrophysics class at Texas State University. The unit encompasses an introduction of the Thirty Meter Telescope (TMT), a local perspective in San Marcos, a history of Hawaii, perspectives about the TMT, and formal ethical frameworks. I will present our preliminary analysis of data from Spring 2020 and 2021, with an emphasis on the students' written work at the end of the unit. Our analysis indicates that students experienced an increased understanding of the complexity of the issue, increased empathy to both sides, and a desire for a compromise. In order to support the physics educator community in teaching about ethics in physics classes, I will highlight what worked well in our design and what could have been improved.

B4-06 - 12:40 p.m. | Contributed | Analyzing Students' Discussions About Ethical Dilemmas in Physics

Presenting Author: Ciana Pike, Texas State University

Additional Author | Alexander Vasquez, Texas State University

Additional Author | Alice Olmstead, Texas State University

Additional Author | Brianne Gutmann, Texas State University

Additional Author | Daniel Barringer, Texas State University

Physicists are likely to encounter ethical dilemmas during their careers. However, physics students are often not taught about ethics during their degrees. It is imperative that future physicists are introduced to the real-world implications of their work in order to develop their ethical reasoning skills. At Texas State University, we have developed and implemented an ethics unit for a new Observational Astrophysics course. The unit is centered on the potential construction of the Thirty Meter Telescope on Mauna Kea. We video-recorded whole class and small group discussions via Zoom from Spring 2021 to study the responses of students throughout the unit. In this talk, I will share examples of how students respond to prompts that invoke their ethical reasoning skills within physics, and consider how they navigate ethical discussions with their classmates.

B4-07 - 12:50 p.m. | Contributed | Teaching Online Courses with Active Learning Techniques

Presenting Author: Raymond Zich, Illinois State University

The conversion of lecture-based physics and astronomy classes to online instruction is reported. The role of active learning techniques in achieving the transition and the results of incorporating active learning in the online courses is discussed. A significant increase in remote and online instruction has occurred because of the COVID-19 pandemic and increased popularity of distance learning. Sustaining student engagement and communication in online classes is critical and can be achieved using active learning techniques. How the active learning techniques were incorporated into the online curriculum, the types of active learning materials used, and the outcomes from the inclusion will be discussed. Pre to post gains from quantitative assessments made with the CLASS, CTSR, TOAST, and LPCI, and qualitative assessment results from interviews and free response surveys will be presented. There were good pre-post gains observed on the concept inventories and students reported satisfaction and improved conceptual understanding.

Session B5: PER: Diversity, Equity & Inclusion

Saturday, Jan. 8, 12-1 p.m.

Moderator: TBA

Sponsor: Committee on Research in Physics Education

B5-01 - 12:00 p.m. | Contributed | Investigating the Impact of HSIs on Physics and PER

Presenting Author: Brianne Gutmann, San José State University

Additional Author | Rebecca Rosenblatt, NSF/EHR/HRD

Hispanic serving institutions (HSIs) are an increasingly large set of higher education institutions. From 2010-2020 the number of HSIs went from 311 to 569. Within the PER community, research perspectives from HSIs have provided critical insights into how to support racially and ethnically diverse students in physics education. This presentation will investigate the number of physics education researchers at HSIs, the fraction of HSIs that have physics education researchers, and demographic data from IPEDS providing information about how HSIs contribute to the diversity of undergraduate physics students and graduate physics students in comparison to other institutions. In addition, we will examine themes from funded research and publications at HSIs to highlight how physics education researchers center their HSI's unique student population in their research and what ways these unique populations advance physics education research.

B5-02 - 12:10 p.m. | Contributed | Reducing the Gender Gap in Introductory Physics Using Interactive Tutorials

Presenting Author: Ryan Massie, University of Cincinnati

Additional Author | Kathleen M Koenig, University of Cincinnati

Additional Author | Alexandru Maries, University of Cincinnati

Additional Author | Robert Teese, Rochester Institute of Technology

The physics gender gap is a well-known discrepancy in performance between male and female students despite having similar prior preparation. With an increase in the use of technology, new ways of instruction have been developed such as Interactive Video-Enhanced Tutorials (IVETs). The IVETs involve web-based activities that lead students through a problem solution using expert-like problem-solving approaches. Several IVETs were evaluated by comparing the performance of students who completed the IVET with those who watched a non-interactive video solution (control group) which utilizes the same problem-solving approaches as the IVET on a paired problem on the same concepts. Results show that for the IVET group, women who had collectively performed worse on the previous exam, either reduced or reversed the gap between them and their male counterparts on the paired problem, while in the control group, there was no difference from the results of the previous exam. Supported by NSF grants DUE-1821391 and DUE-1821396.

B5-03 - 12:20 p.m. | Contributed | Inequity in North Carolina High School Physics Learning Outcomes

Presenting Author: Timothy Osborn, University of North Carolina Chapel Hill

Additional Author | Alice Churukian, University of North Carolina Chapel Hill

In this project we investigated the state of disparities in learning outcomes in North Carolina high school physics classrooms. We proctored the Force Concept Inventory (FCI) to ~1500 first semester, introductory college physics students, who attended high school in NC, prior to college instruction. With an appended demographic survey, we investigated disparities in FCI scores by gender, ethnicity, and highest level of high school physics taken. When controlling for highest level of physics taken, men consistently scored higher on average, with women scoring approximately 62% of what men scored, even while overall student scores increased with higher level of

prior course. When controlling for ethnicity the gender performance gap remained. When controlling for gender we saw performance gaps between white/Asian students and Black/Hispanic students. These results suggest that there may be conditions within North Carolina high school physics classrooms that lead to inequitable learning outcomes among students of differing identities.

B5-06 - 12:40 p.m. | Contributed | Student Storytelling in Physics Courses to Promote Engagement and Diversity

Presenting Author: Roberto Ramos, University of the Sciences

I will report the results of using student story-telling as a pedagogical technique in physics that I have applied to four college courses: a two-semester Introductory Physics course, Modern Physics, and Statistical Mechanics. Students were asked to research biographies of physicists and present 5-7 minute summaries that went beyond a narration of facts and events but provide context and connections. Students were asked to focus on what motivated physicists to study physics, what challenges they faced, their contributions and hobbies apart from physics, and how they interacted with other scientists in their time. A special effort was made to promote story-telling of the background and contributions of women and minorities in physics. I will report on student responses and reactions to this effort, based on blind surveys, exam results and general observations.

B5-07 - 12:50 p.m. | Contributed | Student Attitudes When We Focus on Self-advocacy Through Disciplinary Practices

Presenting Author: Julian Martins, University of Colorado - Boulder

Additional Author | Shelly N. Belleau, University of Colorado - Boulder

Goals for inclusivity can be met in physics classrooms that focus on self-advocacy and empowerment through disciplinary practices, foci that are critical in high school physics courses and pre-service teacher preparation programs. We've published work demonstrating that in such learning environments, learning gains are similar for students from minority and majority groups. These data provide the foundation for PEER Physics, a curriculum-driven professional learning community for both High School physics and teacher preparation. We now evaluate these courses from a new perspective by exploring student attitudes and beliefs towards physics and their physics learning experiences, as assessed using the Colorado Learning Attitudes about Science Survey (CLASS) and student reflections. Comparisons of student attitudes before and after their course experience suggest they came to see science in a way more similar to how experts do, and these shifts in opinion were greater among traditionally underserved student groups.

Session B6: PER: Student Content Understanding, Problem-Solving and Reasoning

Saturday, Jan. 8, 12–1 p.m.

Moderator: TBA

Sponsor: Committee on Research in Physics Education

B6-01 - 12:00 p.m. | Contributed | Perturbation: Analytical vs. Numerical Treatment

Presenting Author: Jay Wang, University of Massachusetts Dartmouth

One of the important but challenging topics students face in introductory quantum mechanics is perturbation theory. Difficulties arise over questions such as validity, namely when a perturbation is considered "small", or what states are "good" in degenerate perturbation theory. We discuss a multipronged treatment of perturbation with analytical approach augmented with numerical and symbolic computation. In this approach we are able to compute and compare against exact results, sometimes analytical but most often numerical, to ascertain the effect of perturbation. Not only does computation help cut down mathematical drudgery, it also enables more in-depth study. For instance, one can find with ease good states beyond the standard 2-state treatment in degenerate perturbation calculations (see <https://jwang.sites.umassd.edu/> for examples).

B6-02 - 12:10 p.m. | Contributed | The Challenge of Evaluating Consistency of Competing Lines of Thinking*

Presenting Author: Andrew Boudreaux, Western Washington University

Additional Author | Mila Kryjevskaja, North Dakota State University

Many curricula challenge students to explain discrepant events. Dual process theories can account for the tension learners experience between competing lines of thinking. When faced with a novel problem, the heuristic process generates an initial model, based on recognition. These models can be inconsistent with formal knowledge, such as Newton's laws, learners have developed. In some cases, cognitive reflection initiates scrutiny of the initial model by the analytic process, with the possibility of formal knowledge being activated. But how readily can learners override a strongly appealing intuitive idea in favor of formal knowledge? In an ongoing collaboration, we have been developing "screening-target" question pairs that elicit normative reasoning in low distraction contexts, but trigger alternative models in related, higher distraction contexts. We have used selected pairs in interviews. This talk shares a case study of a student holding competing reasoning in tension, using dual process theory as an interpretive lens.

*Work supported by the National Science Foundation under Grant Nos. DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, DUE-1821561.

B6-03 - 12:20 p.m. | Contributed | Investigating Student Attitudes and Curricular Benefits from Two Instructional Interventions

Presenting Author: Jeffrey Rosauer, Illinois State University

Additional Author | Grant Kaufman, Illinois State University

Additional Author | Raymond Zich, Illinois State University

Comparisons of the effectiveness of two instructional interventions in a general education physics class on improving students' scientific reasoning skills and attitudes toward science were made. The first intervention was to have students watch short videos on scientific topics while completing worksheets. The second was to have students manipulate PhET simulations and complete worksheets based on those simulations. The instructional interventions were applied for two control semesters, three video treatment semesters, and two PhET manipulation semesters. The Colorado Learning Attitudes about Science Survey was used to assess the students' attitudes about science and Lawson's Classroom Test of Scientific Reasoning was used to assess the students' scientific reasoning skills. Pre and Post assessment results are presented and compared for the control semesters, video activity semesters, and PhET manipulation semesters. Initial findings showed improvements in both student attitudes toward science and students' scientific reasoning skills with both interventions.

B6-04 - 12:30 p.m. | Contributed | Academic and Non-cognitive Factors Affecting FMCE Pretest and Post-test Scores

Presenting Author: Dona Hewagallage, West Virginia University

Additional Author | John C Stewart, West Virginia University

This study investigates how college-level and high-school-level variables affect FMCE (Force and Motion Conceptual Evaluation) pretest and post-test scores. The sample consists of students attending a large eastern land-grant university in the US who are enrolled in the introductory calculus-based mechanics class (N=1060). Variables examined include college performance, high school preparation, and non-academic variables such as sense of belonging, self-efficacy, personality, and demographics. Correlation analysis and linear regression were used to understand relations between these variables. High school physics preparation and student achievement in high school physics were consistently the most important variable in explaining pretest scores.

C1-POS-01 - 1:15 p.m. | Poster | The Approximate Formula for Solar Declination and Its Experimental Validation

Presenting Author: Wojciech Walecki, Mater Academy, Doral College, Miami Dade College

We present a very simple derivation of the commonly used approximate formula [1]: $D = A \cdot \sin((d/365.25) \cdot 2\pi)$, where D is solar declination, $A = 23.44$ deg is Earth's axial tilt (obliquity of the ecliptic), and d is the number of days after Equinox. We used the heliocentric cartesian frame of reference with XY plane coplanar to the ecliptic. We analytically calculated the scalar product of the unit vector pointing from the Sun to the Earth and the other unit vector pointing from the Earth to Polaris. This product is equal to the cosine of the angle complementary to the solar declination D . We also demonstrated how we can find the geographic latitude using hands-on observation of the shadow of a yardstick at local geographic noon. The geographic latitude is found with the accuracy of about 1.5 degree (or 100 nautical miles along meridian).

1. <https://www.pveducation.org/pvcdrom/properties-of-sunlight/declination-angle>

C1-POS-02 - 1:25 p.m. | Poster | Students' Understanding of Factors Related to Space Exploration

Presenting Author: Bahereh Assadi Samie, Temple University

Additional Author | Shannon Willoughby, Montana State University

Additional Author | Janelle M Bailey, Temple University

Space exploration is a naturally interesting topic to many people. With the advances in spacecraft propulsion methods, it is possible for humans to study distant celestial bodies. Students can investigate the benefits and challenges of both human and non-human travel to space through different means. In this study, we investigated ways to help students understand space exploration. Two activities, Migration to Mars and Solar Sails, were designed for an undergraduate astronomy course taught online during the COVID pandemic. Students completed the activities in groups of four. One activity per group was submitted to the course management software followed by a quiz that students answered individually. Quiz responses were coded to check students' understanding of the activities and the extent to which they were able to describe information relevant to space exploration. Students generally understood the value of uncrewed missions and the fact that solar sails use sustainable energy.

C1-POS-03 - 1:35 p.m. | Poster | Space Weather – How The Sun Influences Our Technological Life

Presenting Author: Gerald Rabl, Manhattan College and Queens HS for the Science @ York College

Space weather as an aspect of space science focuses on the study of the solar-terrestrial relationship and related technological impacts. The Sun with its influence on Earth's space environment releases vast amounts of energy in the form of electromagnetic and particle radiation that can damage or destroy satellites, navigation, communication and power systems. Solar coronal mass ejections (CME) not only produce auroral light shows, but also can degrade satellite electronics and cause satellite failures, cause power grid failures and interrupt signals from navigation systems (GPS); additionally, solar flares can block high-frequency radio waves used for radio communication; This presentation will give an introduction how guided and student centered teaching classwork can help students to explore and present a fascinating aspect of our solar system.

C1-POS-04 - 1:45 p.m. | Poster | Experimental Inquiries with the New PASCO Sonometer

Presenting Author: Dan Burns, PASCO scientific

Investigating the physics of music is a reliable way to engage many of your students. A sonometer is a traditional device for learning about the physics of string instruments. The new PASCO sonometer adds new features to this classic experimental apparatus. These features make it quick and easy for students to gather the data they need to answer questions about wave properties, resonance, and standing waves in strings. The PASCO sonometer can be used with modern sound sensors and FFT analysis to measure frequency or "old school" with tuning forks. This presentation will introduce the new PASCO sonometer features, explain how to use it to collect data, and describe several experiments that can be performed with it. Student handouts and teacher guides will be provided.

C1-POS-05 - 1:55 p.m. | Poster | Online and In-Person Preparation Modes for Individual Physics Contest Preparation

Presenting Author: Tamas Orosz, ELTE - Eötvös Loránd University

Students, who are making effort to extend their knowledge are usually looking for educational resources. There are a lot of textbooks, websites with available smart learning materials. However, the success of their learning process may depend on multiple factors. This paper discusses a special case of a contest preparation for the International Physics Olympiad. Our main purpose is to make benefits from students' online experience. Many of them are absolutely professionals in finding excellent learning staffs. However, the teachers' continuous feedback and evaluation are necessary to effectively guide the students how to go on with their studies. It is found out that applying a Canvas environment can successfully support personal discussions.

C1-POS-06 - 2:05 p.m. | Poster | 3D Collision Tracking and Analysis

Presenting Author: Lori Shaaban, Portland State University and Liberty High School

Presenting Author | William Guo, Lincoln High School

Additional Author | Nathan Shaaban, Oregon State University

Additional Author | Ralf Widenhorn, Portland State University

Video assisted object-tracking is commonly used in physics labs, although rarely for 3D motion due to the inefficiency of synchronizing multiple 2D cameras. Using the Intel RealSense D435i, a relatively inexpensive 3D camera, we developed a program combining 3D color tracking with data analysis. In addition to being more convenient and less time-consuming compared to other object-tracking programs, this software has great potential for many interactive lab activities. Herein, we investigate the center of mass of two balls colliding in mid-air. This engages students with concepts of kinematics, momentum, and impulse, and also allows them to refine their understanding of how the center of mass of a system behaves before and after a collision.

A10.3.1-01 - 1:15 p.m. | Contributed | Model-based Simulation of Nonlinear Driven Pendulum Using XCOS

Presenting Author: Sastri Oruganti, Central University of Himachal Pradesh

The non-linear differential equation governing the motion of a driven oscillator is solved using model based simulation approach in XCOS, an application of Scilab. Fixing all initial values, results are simulated for small and large driving amplitudes. While, former results in periodic motion with the frequency of driving force, later leads to chaotic behaviour. To further elucidate the idea of chaos, two pendulums with very slightly differing initial angles are considered and the simulation is repeated. The difference between the two angular positions are plotted to show that while the low drive pendulums reach to synchronous motion with time, the high drive pendulums will show an average behaviour which increases exponentially with time leading to the idea of Lyapunov exponent.

A10.3.1-03 - 1:25 p.m. | Contributed | Chaotic Pendulum in Free Fall

Presenting Author: Toby Dittrich, Portland Community College

The Drop Tower at Portland State University allows investigations of the behavior of physics demonstrations when the acceleration due to gravity goes to zero for 2.1 seconds. Does this cause a chaotic pendulum to transition into non-chaotic behavior or does chaos survive this short transition into weightlessness due to being in a non-inertial frame of reference from free fall? This question will be answered by viewing one of the many demonstrations in the Drop Tower Physics YouTube Channel, and the theoretical reason for this behavior will be discussed.

Session B7: Get the Facts Out: Changing the Conversation Around Physics Teacher Recruitment Saturday, Jan. 8, 1:15–2:15 p.m. Moderator: Drew Isola Sponsor: Committee on Teacher Preparation/Co-Sponsoring: Committee on Physics in High Schools

B7-01 - 1:15 p.m. | Invited | Physics Teacher Recruitment Strategies: New Pathways and GFO Implementation

Presenting Author: Joseph Kozminski, Lewis University

Additional Author | Brandi Fuller, Lewis University

Additional Author | James Hofmann, Lewis University

Additional Author | Dorene Huvaere, Lewis University

As a part of our PhysTEC Recruiting grant, Lewis University is expanding its pathways to physics teaching and modifying GFO resources to enhance its recruiting efforts. In Fall 2021, Lewis launched a five-year BS/MA program in physics and secondary education with licensure, which is expected to be an attractive path for students deciding to pursue teaching later in their college careers and for community college transfers. We have also collected local data and incorporated it into our recruiting materials, developed strategies for recruiting internally and externally, given presentations to faculty and physics majors at all levels, and rolled-out a new website for our physics teacher preparation program. This presentation will provide an update on our successes and challenges in recruiting more students into our physics teacher preparation program. This work is supported by the National Science Foundation and the Physics Teacher Education Coalition (PhysTEC) under grant no. 1707990.

B7-02 - 1:45 p.m. | Invited | Increasing the Number and Diversity of Majors by Advertising Teaching

Presenting Author: Wendy Adams

Did you know? Half of STEM majors are interested in teaching as a profession, and STEM students of color are more interested in teaching as a profession than their White counterparts. If we want these students to consider majoring in a STEM field, it is important to include teaching as one of their career options when entering the major. In this presentation we will share updates on the Get the Facts Out Project including data to support the above claims, new handouts with salary and cost-of-living information for teachers in hundreds of school districts, a new professionally made short video series, and new single-slide conversation starters. We will also share what we learned from a GFO half-day mini-conference where we heard from faculty in physics, chemistry, and mathematics about what they would like to see from GFO in the future.

Session B I : Introductory Courses I Saturday, Jan. 8, 1:15–2:15 p.m.

Moderator: TBA Sponsor: AAPT

B1.1-02 - 1:25 p.m. | Contributed | Using Cell Phones to Develop Core Physics Models in Students

Presenting Author: Nancy Ruzycki, University of Florida

This session will show how cell phones can be used in active learning for students in physics and engineering. We will discuss some of the common apps which can be used and show examples of models which can be developed through active learning (POGIL) styled experiences for students. These cell phone sensors allow students to record, analyze and develop mathematical relationships which help to build core conceptual models in physics students at all levels.

B1.1-04 - 1:45 p.m. | Contributed | A Revised Framework for Interactive Classroom Demonstrations

Presenting Author: Robert Nazarian, Fairfield University

Interactive classroom demonstrations (ICDs) are used extensively in physics, and prior studies indicate that, when conducted under certain conditions, lead to appreciable increases in student gains and retention. The literature suggests that the ICD recipe for maximizing student gain is to i) introduce the physical theory that will be demonstrated, ii) describe the demonstration and prompt students to record a prediction for what will happen, iii) conduct the demonstration, and iv) return to the prediction for students to reconcile their hypotheses. Here, I propose two interrelated updates to leverage the particular strengths of Generation Z students currently enrolled in introductory physics courses as well as to address potential pitfalls in the canonical ICD recipe: the inclusion of simple, yet flashy demonstrations, and the integration of social media to disseminate and further engage with the results.

B1.1-05 - 1:55 p.m. | Contributed | The Scrambled Review Sheet

Presenting Author: Kathleen Harper, Case Western Reserve University

“I would know how to solve the exam problems if you’d just tell me what equation to use.” Many a physics teacher has heard this from students and replied with words similar to, “The exam is testing your understanding of physics, and that includes knowing which concepts apply to the problem situation.” After many such exchanges in my courses, I found myself wondering how I could help students better practice this key aspect of physics success. My answer was the “scrambled review sheet,” where problems from the textbook appear in a random order and students are encouraged to just identify the required concepts and start the problems. I make no claim that this is an original idea, but in this talk I will share the details of how I employ it, along with some observations (of both my students and colleagues!) while engaged with this learning tool.

B1.1-06 - 2:05 p.m. | Contributed | Student Reasoning with Multi-variable Expressions*

Presenting Author: Safana Ismael, North Dakota State University

Additional Author | Mila Kryjevskaia, North Dakota State University

Additional Author | Andrew Boudreax, Western Washington University

Research suggests that students in introductory courses struggle to understand an operational definition of electric field based on the expression $E=F/q$. To investigate factors that impact student reasoning, we developed sequences of questions that ask students to predict how (if at all) variables in the expression are affected when specific changes are made to experimental setups. (For example, when a new test charge is used, or a new source charge is used.) We have also explored the extent to which reasoning approaches identified in this context persist in other contexts involving multi-variable expressions. Dual process theories of reasoning (DPTor) have

been used as a theoretical framework in this investigation. The talk will discuss how DPTOR served to guide the design of the questions and as a framework to interpret student responses.

*This material is based upon work supported by the National Science Foundation under Grant Nos. DUE-1431940, DUE-1431541, DUE-1431857, DUE-1432052, DUE-1432765, DUE-1821390, DUE-1821123, DUE-1821400, DUE-1821511, DUE-1821561

Session B4.1: PER: Curriculum and Instruction **Saturday, Jan. 8, 1:15–2:15 p.m.**

Moderator: TBA **Sponsor: Committee on Research in Physics Education**

B4.1-01 - 1:15 p.m. | Contributed | Scientific Argumentation in the Secondary Physics Classroom

Presenting Author: Zac Patterson, The Ohio State University

Additional Author | Guofu Ma, The Ohio State University

The focus of this project is to analyze how teachers employ writing and discussion as argumentative practices in science classrooms and how, in turn, their students learn to participate in these new practices as opportunities to learn science content. We define the teaching and learning of argumentation as a diverse set of situated ways of using spoken and written language (and related semiotic systems) for articulating a warranted perspective. This involves events such as the exploration of a topic, inquiry, advancement of knowledge, dialogue with others articulating alternative positions, the construction of social relationships both among those co-present and between authors and readers as competitive or collaborative. This paper analyzes data collected during a two-week instructional unit on Newton's Third Law in an accelerated secondary physics classroom. Data collection methods include video recordings, in-person observations, and semi-structured interviews with the instructor and students.

B4.1-02 - 1:25 p.m. | Contributed | Incorporating an Initial Basic Competencies Video Creation Assignment into Courses

Presenting Author: Kathleen Falconer, Universität zu Köln Institut für Physikdidaktik

Additional Author | Dan MacIsaac, Buffalo State College

Additional Author | Bradley Gearhart, Hutchinson Central Technical High School, Buffalo Public Schools, NY

Additional Author | Stefan Hoffmann, Universität zu Köln Institut für Physikdidaktik

As a component of student produced video projects, one of the authors created an initial basic competencies assignment using a smart phone or other hand-held device as video creation and editing tool. The assignment was designed to facilitate the development and the assessment of the students' skills in using the smart phone. Many students, especially high school students, have not used editing apps with many of the features useful in the making of an explanatory science video. We will discuss the integration of this initial basic competencies assignment into a media course for physics students. We will discuss several action research cycles of the initial basic competencies assignment development and implementation.

B4.1-03 - 1:35 p.m. | Contributed | Instruction to Improve Student Understanding of Gravity and Weight

Presenting Author: Xiangqun Zhang, Zhenjiang Experimental School

Additional Author | Lei Bao, The Ohio State University

Existing literature has documented persistent student difficulties in understanding the concepts involving weight and gravity. In the literature and textbooks, there are two versions of weight definition in terms of (1) the gravitational force applied on an object (the gravitational definition) and (2) the force applied on the supporting object (the operational definition). Studies have indicated that using the operational definition in teaching can be more effective than using the gravitational definition. However, curricula using the gravitational definition are widespread, which make it important to explore how this approach can be made effective. In this study, the effectiveness of the instruction based on the gravitational definition is investigated in a Chinese middle school. A conceptual survey on weight and gravity has been developed and used in pre-post testing. The results show that using the gravitational definition can also be effective in teaching middle school students.

B4.1-04 - 1:45 p.m. | Contributed | Effectiveness of Computational Exercises in a General Education Astronomy Course

Presenting Author: Quinn MacKenzie, Illinois State University-Physics

Additional Author | James DiCaro, Illinois State University-Physics

Additional Author | Raymond Raymond, Illinois State University-Physics

We report on the incorporation of computational exercises into a single semester general education and the efficacy of the inclusion. Computation is an effective tool for creating deep conceptual understanding, connecting concepts with mathematics, and introducing prediction in science. Fifteen spreadsheet-based computational exercises were introduced into the course as active learning activities and were collaboratively completed. Student learning pre to post was measured with the TOAST and LPCI, with pre to post correctness gains of 20% were measured on the TOAST and 29% on the LPCI. Qualitative data was collected in the form of free response surveys to investigate student learning, attitudes toward computational exercises, and overall perceptions of the course. Student responses toward inclusion of computational exercises were positive. In addition to the overall results from the TOAST and LPCI, student responses to individual questions were analyzed for patterns of correct and incorrect responses and correlations between questions.

B4.1-06 - 2:05 p.m. | Contributed | QuSTEAM: A New Curriculum Development Project in Quantum Information Science

Presenting Author: Christopher Porter, The Ohio State University

Additional Author | Zahra Atiq, The Ohio State University

Additional Author | Edward Fletcher, The Ohio State University

The severe human-resource shortage in all areas of quantum science, technology, engineering, and mathematics is projected to significantly slow the societal impact of the second quantum revolution. To address this need and accelerate the NSF Quantum Leap, a comparable leap in education strategy is required. QuSTEAM (Quantum Information Science, Technology, Engineering, Arts and Mathematics) will provide a national educational model for the emerging field of quantum information sciences (QIS). The development relies on research-based practices to provide a convergent and inclusive curriculum to a diverse community of future scientists and engineers, a curriculum that is modular and conducive to in-person, online, and hybrid delivery modalities. In this talk, we will present an outline of the work, which is still in early stages. We will describe emerging themes in training needs from the industry, as well as faculty and student priorities. Some overview of early modules will also be presented.

B5.1.1-01 - 1:15 p.m. | Contributed | Graduate Physics Programs During COVID-19: Admissions, Resilience and Diversity

Presenting Author: Christopher Porter, The Ohio State University

Additional Author | Galen Pickett, California State University Long Beach

Additional Author | Geoff Potvin, Florida International University

The sudden COVID-19 outbreak introduced unexpected barriers and uncertainty for prospective graduate students and physics departments. Chief among concerns are the safety and health of students, recruitment, economic shortfalls resulting from reduced enrollment, and effects on the diversity of incoming graduate cohorts. More recently, programs have attempted to return to “normalcy”, while still ensuring the safety of students and employees. Our group is conducting surveys of students and physics departments, augmented by follow-up interviews with both groups, from fall 2020 and extending through spring 2022. Though data collection will still be in progress, we will report preliminary findings on how COVID-19 has impacted the processes, pressures, and demographics of physics graduate programs. We will also discuss the resilience of various programs, with special attention paid to those that have been successful in maintaining the size, diversity, and preparedness of the 2020 and 2021 graduate cohorts.

Acknowledgments/Footnote: This project is funded by the American Physical Society (APS) Innovation Fund through Award IF-5.

B5.1.1-02 - 1:25 p.m. | Contributed | Adaptive Problem-Solving for Contest Preparation

Presenting Author: Tamas Orosz, Department of Data Science and Engineering / ELTE - Eötvös Loránd University

Students need comprehensive knowledge and conceptual understanding to solve Physics Contest problems. International Physics Olympiad is open for High School students from 9 to 12 classes. Students from the same class, and certainly from different classes, have usually different backgrounds. However, those students who manage to go to the Olympiad, should be expert in all the topics of the Official Syllabus. The courses, therefore, starts from the basic concepts, theories, and problems to advanced materials. There is not enough time to discuss all problems in detail. Instead, complex problems are selected, and the corresponding learning building blocks are highlighted. Students get links to relevant basic problems, which help to understand and practice the details of complex problems. Hybrid education makes more difficult to share suitable materials. A computer aided adaptive informatics tool is being built to provide required examples, and to make continuous feedback and evaluation of the students' knowledge.

B5.1.1-03 - 1:35 p.m. | Contributed | Observation Brain Activation When Solving Physics Problems Using fNIRS

Presenting Author: Hwa Kuk, Department of Physics Education, Korea National University of Education

Presenting Author | Kwang-Su Ryu, Department of Physics Education, Korea National University of Education

In this study, the brain activation characteristics of students who solve physics problems were identified by identifying brain activation changes in real time using functional near-infrared spectroscopy (fNIRS). In this study, 10 questions were selected in consideration of the difficulty of the physics problem, and the subjects were 7 undergraduate students. The research results are as follows. First, after starting problem solving, the amount of brain activation change in students increased significantly, and after problem solving was completed, the amount of brain activation change decreased sharply. Second, the higher the difficulty of the problem, the higher the amount of change in brain activation in most students. Finally, brain activation of high-scoring students occurred throughout the prefrontal cortex compared to those who received middle or low scores.

B5.1.1-04 - 1:45 p.m. | Contributed | Developing Question Sequences to Identify and Remedy Student Reasoning Inconsistencies

Presenting Author: Kristin Kellar, University of Washington

Additional Author | Paula Heron, University of Washington

Dual process theories of reasoning suggest that humans reason using System 1 (heuristic) and System 2 (analytic) thinking processes. The aim of this research is to develop question sequences that serve two purposes: 1) to identify physics students with relevant content knowledge who nevertheless relied on System 1 thinking on a “target” question, and 2) to help students recognize reasoning inconsistencies and activate System 2 thinking effectively to override initial incorrect responses. Screening and target questions are used to identify students making reasoning errors, and intervention questions are designed to alert students of the need to reevaluate their reasoning. Students then have an opportunity to re-answer the target question. Data from recent iterations in calculus-based physics courses at the University of Washington will be discussed.

This study is supported by the National Science Foundation under Grant No. DUE 615418.

B5.1.1-05 - 1:55 p.m. | Contributed | Pre-instruction Math Quiz May Predict Students' Physics Course Performance

Presenting Author: David Meltzer, Arizona State University

Additional Author | Dakota H. King, National Heart, Lung, and Blood Institute, National Institutes of Health

Additional Author | John D. Byrd, Arizona State University

In a five-year multi-institutional study, we have administered a small set of pre-college mathematics problems to nearly 7000 students enrolled in introductory college physics courses. We found consistently that over 30% of students have considerable difficulty with basic algebraic, trigonometric, and graphing operations, with symbolic representations posing a particularly notable obstacle. We will present our most recent findings, including substantial evidence that student performance on even a small set of these types of problems may be able to provide early warning of probable weak course performance.

Supported in part by NSF DUE #1504986 and #1914712

B5.1.1-06 - 2:05 p.m. | Contributed | Teaching Problem Solving in One-Dimensional Kinematics Using Interactive Video-enhanced Tutorials

Presenting Author: Kathleen Koenig, University of Cincinnati

Additional Author | Alexandru Maries, University of Cincinnati

Additional Author | Lora Sheppard, Mason High School

Additional Author | Robert Teese, Rochester Institute of Technology

Helping students develop problem solving skills is a common learning outcome in introductory physics which can be challenging to achieve, particularly in large enrollment courses. This presentation showcases one of our web-based Interactive video-enhanced tutorials (IVETs), which guides students through an expert-like problem-solving approach for a challenging problem involving a given topic, such as one dimensional motion involving two moving objects. IVETs include mini-lectures by a narrator interspersed with branching multiple choice questions that include feedback, allowing students who require less guidance to navigate the tutorials quickly, while students who struggle receive more support according to their needs. This presentation will focus on our One-Dimensional Kinematics IVET and provide details about its design features and impact on students' problem-solving abilities.

Supported by NSF grants DUE-1821391 and DUE-1821396.

B7-01 - 1:15 p.m. | Invited | National Online Physics Olympiads in Latvia*Presenting Author: Ludmila Belogradova, University of Latvia**Additional Author | Inese Dudareva, University of Latvia**Additional Author | Janis Bukins, Latvian Association of Physics Teachers*

Physics Olympiads can be used as one of the enrichment measures to supplement formal school teaching in raising student motivation and developing their skills and talents. Since 2012, the second (county) stage of the Latvian State Physics Olympiad has been taking place online on the Moodle-based platform, gathering more than two thousand 9th-12th grade students every year (around 5% of the number of 9th-12th grade students in the country). We will inform about the organization of online physics olympiads and their results, as well as provide an opportunity for participants to connect and try their hand at solving the tasks of the Olympiads. We will share research results from the research group of the University of Latvia about the motivation of students and teachers to participate in physics olympiads, as well as on the differences in the performance of girls and boys in different stages of physics olympiads.

B7-02 - 1:25 p.m. | Contributed | Beats, Overtones, and Musical Temperament*Presenting Author: David Kordahl, Centenary College of Louisiana*

Introductory physics students routinely learn about acoustical beats as a consequence of wave interference. This example is sometimes used to gesture toward heterodyning in commercial radios. Introductory physics students also learn about the overtone series as a consequence of standing waves. Overtones are then used to explain musical timbre and to hint at the importance of Fourier methods. Yet acoustical beats and the overtone series are rarely linked in introductory physics, despite the fact that musicians habitually listen for beats to tune their harmonies. Acoustical beats and harmonic overtones can be related simply, without any extra physics background, and their relationship leads directly to the problems of musical temperament that have bedeviled musical theorists ever since Pythagoras. Such problems are outlined in this talk, along with suggestions for further reading.

B7-03 - 1:25 p.m. | Contributed | Building a Physical Science of the Arts Course*Presenting Author: Renee Lathrop, Dutchess Community College*

In Spring 2018, I was approached by the Art/Communications/Theater instructors about the unhappiness of their students with the science course options at our school. After talking with them, I applied for release time at our school and was allowed time to build some lab activities that better connected Art, Theater, Music to topics studied in our conceptual physics course. The new lab activities were implemented, and we coordinated the offering of this course with the program chairs in the arts and saw a dramatic increase in enrollment numbers (enrollment increased by 220% in this course). I will present some lessons learned from this experience in building a successful general science course focused on interesting Art/Theater/Communication/Music students.

B7-04 - 1:35 p.m. | Contributed | Paper Choreography Framing of Learning and Teaching Physics*Presenting Author: AdeBanjo Oriade, University of Delaware*

Here is an opportunity to build two modular Origami structures, an Octahedral Skeleton (OS) and a turbine. You will need 12 square sheets of paper. The OS represents 3D space, and the turbine can be used to practice rotational motion physics. The second goal is having conversations about framing, as it relates to attracting students to physics and supporting them in physics. For over a decade I have used paper model building to guide learning Physics and Mathematics. In classes for students with majors other than the sciences we use paper to learn physics concepts, skills, and work on design and Art. Teaching an Origami Science class online led to my use of GIFs for instruction. In the GIFs paper in 2D danced into a final 3D object. This dance inspired paper choreography framing of teaching and learning physics. Many students take the class to fold, and end up doing physics.

Origami Science is a course in which students learn and actuate, science, mathematics and engineering concepts and skills; using paper folding, a math set, and videos. This course runs in the Dupont Interdisciplinary Science Learning Laboratories, University of Delaware, Newark, Delaware.

B7-05 - 1:45 p.m. | Contributed | Harnessing Visual Arts to Teach About The Light And Color*Presenting Author: Tetyana Antimirova, Ryerson University*

In our modern society, science and art are often perceived as unrelated endeavors. However, the idea that artistic creativity and imagination can play an important role in natural sciences and engineering is finally gaining an acceptance. One of the big questions about the connection between art and science is what features make the work of art look realistic. Questions like this open the dialog between physicists and a public. For example, examining paintings, drawings, and photographs can be used to demonstrate the laws of optics. The presentation will demonstrate how the understanding of basic optics phenomena such as an absorption, scattering, reflection, refraction, diffraction, and polarization of light, is absolutely essential for creating realistic-looking paintings and drawings. Using arts in science and engineering education and outreach has a potential to attract and captivate the new audiences.

B7-06 - 1:55 p.m. | Contributed | Including Art Projects as Part of Physics Courses*Presenting Author: Timothy McCaskey, Columbia College Chicago*

Columbia College Chicago specializes in arts and media disciplines, and as a result, our most popular physics classes are "The Science of Acoustics" and "Science of Musical Instruments." Also, I have taught a course called "Physics for Filmmakers" (1) for over a decade where students create a final film project using topics and examples of their choice. I will discuss ideas from recent projects including some done over a recent remote term. I also will discuss plans to transition that course to a conceptual physics course which includes the best discussions and project prompts from "Filmmakers" but is also open to projects in music (2) and other forms of the arts.

(1) T. McCaskey, "Physics for Filmmakers: Goals, Tracker labs, and projects." 143rd AAPT National Meeting, Omaha, NE, 2011.

(2) T. McCaskey and L. Nasser, "Composing Music to Illustrate Concepts in Fractals and Chaos." Poster at the 155th AAPT National Meeting, Cincinnati, OH, 2017.

C3-POS-01 - 1:15 p.m. | Poster | Predicting At-Risk Students in Introductory Physics Using Machine Learning*Presenting Author: John Pace, West Virginia University**Additional Author | John Stewart, West Virginia University**Additional Author | John Hansen, West Virginia University*

Logistic regression, random forest, and ensemble classification algorithms are used to predict students at risk of receiving a failing grade (D or F) in an introductory mechanics class. Institutional variables as well as student performance variables gathered from the first two weeks of class are used. Due to the imbalanced nature of the data, upsampling methods such as synthetic minority oversampling technique (SMOTE) and alternative metrics such as balanced accuracy for evaluating model performance are examined. The importance of variables to the final classification is explored. The best performing models are found to achieve a balanced accuracy of around 80%.

C3-POS-02 - 1:25 p.m. | Poster | How Perceived Objectivity in Physics Impacts Cultural Relevance in Teaching*Presenting Author: Clausell Mathis, University of Washington - Seattle**Additional Author | Abigail R. Daane, South Seattle College*

Over the last 25 years, educational researchers have encouraged practitioners to acknowledge and include culturally relevant pedagogy in physics learning. We examine current physics instructors' views of objectivity in physics and their views of culturally relevant pedagogy. Instructors' statements are analyzed using the conceptions of Culturally Relevant Pedagogy (CRP) listed in Ladson-Billings' (1995) framework: Conceptions of Self and Others, Conceptions of Knowledge, and Social Relations. We interviewed 11 physics instructors asking about their views towards CRP and objectivity in physics. Interviews were transcribed and analyzed using thematic analysis. We share two illustrations of instructors who had strong Conceptions of Knowledge that supported CRP: they focus on the knowledge of physics as being constructed and reconstructed - now and into the future. Findings from our study indicate that the third conception, Conceptions of Knowledge, is crucial to develop if we want physics instructors to truly and effectively use CRP.

C3-POS-03 - 1:35 p.m. | Poster | Investigating Open-Ended Responses to the PMQ Using Natural Language Processing*Presenting Author: Patrick Johns, Michigan State University - East Lansing, MI**Additional Author | Rachel Henderson, Michigan State University - East Lansing, MI*

Student understanding of measurement uncertainty is a common learning goal among introductory physics lab courses. In this study, we investigate the open-ended responses to the Physics Measurement Questionnaire (PMQ) from students enrolled in the two-semester Design, Analysis, Tools, and Apprenticeship (DATA) Lab course at Michigan State University. Using an unsupervised natural language processing technique, Latent Dirichlet Allocation (LDA), we were able to extract themes/topics from student responses to this assessment which were in line with the paradigms recently published by Pollard et al. The extracted themes from LDA were then compared to previously hand coded responses. Comparing the prevalence of the extracted topics to the frequencies of the hand-coded responses led to close agreement between the two analyses. Based on these results, topic modelling techniques may be able to provide insight into student understanding of measurement reasoning.

C3-POS-04 - 1:45 p.m. | Poster | Creating Connections*Presenting Author: Carlton Smith,* University of Florida*

The Learning Assistant Program is a relatively recent advancement in undergraduate education. The core tenet of the program aims to have undergraduate students use instructor-approved and research-backed group activities and discussions along with general peer support to encourage active participation in the course they assist in. Students requiring special accommodations make up a significant portion of students. In this poster, learning assistant anecdotes of interactions with these populations are presented. The use of learning assistants and dialogue between pertinent entities, the instructor, and the student as a means of allowing needed flexibility in these courses are explored.

*Sponsored by: Sujata Krishna, Ph.D.

C3-POS-05 - 1:55 p.m. | Poster | The Growth of a Physics Learning Assistant Over Four Semesters*Presenting Author: Chadrick Schwipper, University of Florida**Additional Author | Sujata Krishna, University of Florida*

The Learning Assistant (LA) Program can be used as a pathway for students to develop pedagogical skills and gain independence in a variety of different learning environments. Here we describe the growth of a Physics LA over four semesters. Starting with a course in pedagogy along with the active facilitation of group learning, we can see the LA creating a strong foundation in their educational skills. Through diversity and inclusion trainings, the LA can start to cater to the different learning styles of students more effectively. As the LA becomes more adept in assisting students, they can take on more independent tasks like running discussion boards, providing exam reviews, and hosting office hours. After just four semesters, we can see the LA becoming self-sufficient in the classroom setting. Throughout their experience, the LA continually receives mentoring from professors and establishes rapport with peers of similar paths.

C3-POS-06 - 2:05 p.m. | Poster | Students Mentoring Students Eases Diversity Conversation and Increases Success Rates*Presenting Author: Gabriel Cardoso, Stony Brook University**Additional Author | Glenda Denicolo, Suffolk County Community College**Additional Author | Marivi Fernandez-Serra, Stony Brook University*

The Physics graduate program of Stony Brook University attracts students from diverse backgrounds, and involves a very intense workload right from the beginning. This made it clear that it is necessary for the department to provide help in adapting to the environment, which led to the creation of a mentoring program. In the past three years, this program has undergone significant changes, the foremost being that it is heavily student-led. Besides faculty mentors, very active student mentors are assigned. This has formed a basis for improved communication between the incoming students and the department, with various benefits which range from success in making through the program requirements to overall mental health. In this talk, I will present the main characteristics and results, obtained through anonymous surveys, of this mentoring program. In the end, I will also discuss possible extensions of these methods to undergraduate programs in the US.

C3-POS-07 - 2:15 p.m. | Poster | PER Outside Research Universities: A Solo PER Perspective*Presenting Author: Andrew Mason, University of Central Arkansas*

One of the broad concerns about the future of physics education research is a relative paucity of active PER groups at colleges and universities that are not primarily focused upon research. Yet, institutions that are primarily focused on teaching need to replicate these studies directly, whether to confirm that results at different university types are similar, or to identify differing outcomes that are connected to institutional type. Differences in institutional focus attract different student populations, and hence, different student motivations, which can directly affect data results from long-recognized quantitative and qualitative measuring instruments. This poster outlines

a preliminary “lay of the land” view from the perspective of a solo PER researcher working at a regional comprehensive state university – both as an example of a non-research university and looking at other teaching-focused institution types – in order to determine the current outlook of PER’s growth outside the research university.

Session B7.1: Physics in Unexpected Places Saturday, Jan. 8, 1:15–2:15 p.m. Moderator: Jonathan Perry

Sponsor: Committee on Science Education for the Public / Co-Sponsoring: Committee on Physics in Pre-High School Education

B7.1-02 - 1:25 p.m. | Contributed | Engaging Physics Students with the Wheel of Time

Presenting Author: W. Brian Lane, University of North Florida

Amazon Prime’s much-anticipated television adaptation of The Wheel of Time book series premiered in November 2021. The series is based on broadly acclaimed source material and features a talented and diverse cast and writing staff. With a market continuing to demand high-fantasy entertainment, the show is expected to entertain for years to come. This premiere also presents an opportunity for physics educators to engage with students, as the original series author, the late Robert Jordan, majored in physics and consistently incorporated his physics background into the story’s setting. I review some of the history of this series and outline thoughts for how we might use this material to engage our students in discussion of physics concepts and representation in the physics community.

B7.1-03 - 1:35 p.m. | Contributed | Physics, Science Literacy, and Human Rights: You Can Get Involved!

Presenting Author: Kristin Poduska, Memorial University of Newfoundland & Labrador

Additional Author | Jonathan Drake, American Association for the Advancement of Science

As an educator, I like to advertise that physics degree holders are adept and flexible problem solvers who can apply their training to diverse and complex real-life issues. To lead by example, I started work with colleagues at the American Association for the Advancement of Science (AAAS) who facilitate an On-Call Scientists program in the area of Human Rights, Law, and Ethics. I describe our work related to helping international human rights advocacy groups parse local court decisions and government policy documents to assess what climate impacts might be implied for their human rights work. The role of the AAAS is to help groups assess whether such decisions or policies are based on good science, by giving organizations targeted science literacy resources so that they know if and when more detailed help (e.g. from AAAS On-Call Scientists) might be appropriate. I also explain how physics training helps this initiative.

B7.1-05 - 1:55 Pp.m. | Contributed | An Intuitive Way to Understand Curved Spacetime

Presenting Author: Jose Mazzini

The standard view is that space and time act together, putting aside the energetic component, leaving STR to paradox over it. GTR clears this up and deals, inclusively, with accelerated frames, where energy acting over spacetime is the essential part of the GTR equation. Still, the primary attention is over, the challenged to imagine Minkowski’s 4-dimensional spacetime. Their representation commonly expresses a curved space & time consequence of energy over spacetime instead from its origins, the equivalent moving space by the presence of proper energy and the surrounding ones.

B7.1-06 - 2:05 p.m. | Contributed | Summer Short Course on Astrodynamics for Incoming STEM Majors

Presenting Author: Angela Capece, The College of New Jersey

Additional Author | J. Lynn Gazley, The College of New Jersey

This talk describes a two-week module on astrodynamics developed for incoming STEM students. The goal of the module is for students to design and simulate a mission from Earth to Venus using the Hohmann transfer---a space maneuver used to travel between two planetary orbits. This application was selected because it utilizes a variety of introductory physics topics. The participants were all low-income, Pell-eligible college students; most were Black, Hispanic, and/or first-generation college students. This group is most at risk of leaving STEM, yet 80% of students who took this course were retained in STEM. In this talk we will present the course learning objectives, details of the Hohmann transfer simulation in VPython, and student outcomes including grades, retention rates, and survey results. This module could be replicated at the high school or college levels to help students achieve proficiency in programming while learning basic physics and astronomy content.

Session A 4.1: Quantum Education at the K-12 Level/High School Saturday, Jan. 8, 1:15–2:15 p.m. Moderator: TBA

Sponsor: Committee on Science Education for the Public / Co-Sponsoring: Committee on Physics in High Schools

A4.1-02 - 1:15 p.m. | Contributed | Modification of Newton's Second Law of Motion

Presenting Author: Amritpal Nafria

In this paper, the effect of resistances on applied force has been studied practically. It has been observed that in every action some part of the applied force is required to overcome the effect of resistances (friction, air resistances, etc.); and when applied force exceeds that amount only then a body accelerates but this force never calculated. Therefore, a mathematical expression ' $F=ma+r$ ' has been provided by including a factor describing above said resistances. Further, such circumstances are discussed when mass of a body is not constant, when force increases on a body moving at the speed of light (hypothetically).

A4.1-03 - 1:25 p.m. | Contributed | The Free AP Physics 1 Course on Kudu.com

Presenting Author: Dan Burns, PASCO scientific

Kudu.com is a web-based online platform that provides customizable textbook content, engaging videos, and auto-graded online homework questions. Homework questions can be used to conduct live clicker sessions where students use phones, tablets or laptops to respond as instructors see instant results. Instructors can add their own questions and access questions uploaded by others. They can edit the content, sequence, and structure of the text and embed additional videos and links. Up to now Kudu courses were used only by universities like UCLA and UC San Diego. A new AP Physics 1 course was added this year and is free for high school instructors and students to use. Skeptical? Kudu.com guarantees the AP Physics 1 course will remain free in perpetuity. This presentation will go into detail about the AP Physics 1 course’s features and how to access and use them.

A4.1-04 - 1:35 p.m. | Contributed | Teaching Quantum Computing to High School Students

Presenting Author: Ciaran Hughes, CERN

Presenting Author | Anastasia Perry, Illinois Mathematics and Science Academy

The open-access book “Quantum Computing for the Quantum Curious” was used to introduce quantum computing concepts to 10th through 12th-grade students at Illinois Mathematics and Science Academy and Phillips Academy Andover. This presentation will describe topics and activities from the book which were well received by students, some challenges, and student feedback. We hope this will provide helpful pointers and ideas for teachers who are interested in bringing QC-related topics into their high school or undergraduate classroom.

B8.1-01 - 1:15 p.m. | Contributed | Perceived Effectiveness of Peer Interaction in Physics Courses

Presenting Author: Alison Page, Miami University

Additional Author | Jennifer Blue, Miami University

Physics remains an area of STEM with lower amounts of diversity among the student population, therefore it becomes important to consider how classroom culture may contribute to a lack of belonging for students in underrepresented groups. This study aimed to determine how students in physics courses at Miami University perceived peer interactions in their courses during formal and informal group work. Virtual interviews were conducted with nine physics majors and responses were coded for positive and negative statements related to themes of respect, contribution, outcome of the task and overall class culture. It was found that on average male students had a higher percentage of positive statements about class culture, while female students had a higher percentage of positive statements about task outcomes and a higher percentage of negative statements about communication and class culture.

B8.1-02 - 1:25 p.m. | Contributed | Getting to Mars – Applied Astrodynamics Visualized

Presenting Author: Richard Gelderman, Western Kentucky University

Orbital calculations are a major player in the story of Andy Weir's "The Martian." The crew originally gets from Earth to Mars by firing rockets to convert a circular orbit around Earth into an elliptical orbit around the Sun which intersects the orbit of Mars. A planetarium allows us to picture how this path makes sense. It is also easy to see why "a straight line is the shortest distance between two points" is not going to be a viable axiom to travel between worlds. This brief visualization could stand alone for a general population of learners, or be combined with mathematical-based arguments in higher level courses.

B8.1-03 - 1:35 p.m. | Contributed | Planetarium Potentials

Presenting Author: David Hostetter, Planetarium Curator (retired), Lafayette Science Museum

Most people likely think of learning the constellations of the night sky when they think of planetariums, but that's not going to help you teach physics. It may not even really be astronomy, but more like sky geography! I think it's important to teach 21st Century astronomy and physics whenever possible, and planetariums can help with so much more than just constellations. Planetariums can do things that regular classrooms cannot do. This in-dome presentation will look at both specific and general ways that planetariums can help you teach physics and astronomy.

B8.1-05 - 1:55 p.m. | Contributed | Identifying Tempered Radicals in the STEP UP Advocate Program*

Presenting Author: Benjamin Archibeque, Florida International University (FIU)

Additional Author | Joinee Taylor, Florida International University (FIU)

Additional Author | Pooneh Sabouri, Florida International University (FIU)

Additional Author | Zahra Hazari, Florida International University (FIU)

The STEP UP project (STEPUPphysics.org) was designed to reduce barriers for high school women in physics and encourage them to pursue an undergraduate physics degree, in which women have been underrepresented historically. STEP UP focuses on implementing high school interventions by recruiting high school physics teachers, called Advocates, who are trained to teach STEP UP's research-driven materials in their classroom. To understand the effects of material implementation on Advocates, surveys are being administered to them before and after the school year. Using a "tempered radicals" framing, this talk will present an analysis of initial survey responses describing the characteristics of teachers who are willing to be disruptive in order to reduce barriers for women and change the physics classroom culture. Results will inform our understanding of teachers and the ways in which we can support their development as tempered radicals.

*This work is supported by the National Science Foundation under Grant No. 1720810, 1720869, 1720917, 1721021, and 1038321.

B8.1-06 - 2:05 p.m. | Contributed | The 2021 Inclusive Curriculum in Physics Workshop Series*

Presenting Author: Mel Sabella, Chicago State University

Additional Authors | Juan Burciaga (Colorado College) Beth Cunningham (American Association of Physics Teachers) Felicia Davenport (Georgia Tech) Sara Frederick (Vanderbilt University) Meseret Hailu (Arizona State University - Mary Lou Fulton Teachers College) Alexis Knaub (American Association of Physics Teachers) Arielle Phillips (University of Notre Dame) ReAnna S. Roby (Vanderbilt University) Farrah Simpson (Brown University), see above

The 2021 Inclusive Curriculum in Physics Workshop Series is a three part series organized and led by the National Society of Black Physicists, the National Society of Hispanic Physicists, and the American Association of Physics Teachers. The series leverages the expertise of equity, diversity and inclusion (EDI) experts, as well as an organizing team of physics students, faculty and STEM professionals at different stages of their studies and careers. The purpose of the series is to: Explore the importance of EDI in the classroom and the existing instructional materials that focus on EDI, with members of the broad physics education community; Engage participants in discussion and action items around the current challenges to equity in STEM education with input from experts in the field; Provide support to working groups through a network of partners to engage in specific physics education projects using the lens of inclusion.

* Made possible through a grant from the American Institute of Physics Diversity Action Fund.

B9-01 - 1:15 p.m. | Contributed | Using Online Whiteboards in Physics Class

Presenting Author: Dennis Garvey, State College of Florida

The use of online whiteboard services in teaching physics will be discussed. Online whiteboards allow for much easier monitoring of student calculations than is possible with students writing on traditional 2ft x 3ft physical whiteboards. Using a service like Idroo.com allows each student to work on their own whiteboard using an equation editor interface. Meanwhile the teacher has a tab open in a browser showing each student's whiteboard. Monitoring the work of the whole class is as easy as clicking from tab to tab. It allows for the teacher to be there "just in time" to provide help when a student gets stuck. Time is saved by having all chapter equations already typed out on each student's whiteboard. Students can "copy and paste" the pertinent equations straight into the beginning of their own calculations. Iroo.com is free to use for the students (but not the teacher).

B9-02 - 1:25 p.m. | Contributed | A Simple Nuclear Lab To Measure The Electron's Rest Mass

Presenting Author: Daniel Marble, Tarleton State University

Additional Author | Christopher B Marble, Texas A&M University

Additional Author | Kassie S Marble, Texas A&M University

In Advanced Lab classes, students often perform labs on radioactivity and nuclear spectroscopy as well as labs measuring several fundamental constants. Advanced labs classes can pose a problem for smaller public institutions as these classes usually have low enrollments and having multiple traditional lab setups is costly. However, advances in digital electronics have enabled the development of low cost (<\$2000), easy to use nuclear spectroscopy systems that can provide multiple lab activities. In addition to the traditional radioactivity and shielding labs, these systems can also be used with exempt radioactive sources to provide other laboratory activities including measuring to around 5%: 1) the charge of an electron using x-ray fluorescence and 2) the mass of an electron using Compton scattering. This eliminates the need for additional laboratory equipment making such labs more accessible to both undergraduate institutions and high schools.

B9-03 - 1:35 p.m. | Contributed | Relativistic Wave Mechanics for Undergraduates

Presenting Author: Robert Close, Clark College

It is customary to introduce students to quantum mechanics with the Schrödinger equation because the single-component wave function is easy to handle mathematically. However, the Schrödinger equation is not consistent with special relativity, nor does it describe spin angular momentum. We propose that the Dirac equation provides a better introduction because (1) it is consistent with the laws of physics, (2) it describes spin angular momentum, and (3) it is easily derived from the classical physics model of an ideal elastic solid. The resultant description of classical wave mechanics shares many features of relativistic quantum mechanics. These include Lorentz invariance, bispinor wave functions, half-integer azimuthal quantum numbers, standing waves with circular wave propagation, particle classifications similar to fermions and bosons, operators for physical quantities including spin angular momentum, Pauli exclusion principle, and interaction via potentials. The Schrödinger equation approximates the evolution of a single wave function component.

B9-04 - 1:45 p.m. | Contributed | Free Expansion of a Gaussian via Squeezed Harmonic Oscillator States

Presenting Author: James Freericks, Georgetown University

Additional Author | Sandro Orjuela, Bowdoin College

A free Gaussian can be thought of as the ground state of a simple harmonic oscillator with the frequency adjusted to give the initial variance of the Gaussian. The free Hamiltonian, when expressed in terms of the raising and lowering operators, can be thought of as a squeezing operator acting on the SHO ground state. We show how this mapping can be used to understand the increasing variance of the Gaussian as it evolves in time. In cases where time evolution is taught after the operator method solution of the SHO, then one can explain free expansion in this alternative framework. One can even perform the calculation using only operator manipulations, instead of solving the time-dependent Schrödinger equation. We sketch how this is done. It requires the Weyl form of the BCH formula, the Hadamard lemma, and the exponential disentangling identity. This work was an REU project.

B9-05 - 1:55 p.m. | Contributed | Physics Undergraduate Advanced Labs During Covid-19 Pandemic

Presenting Author: Pratheesh Jakkala, University of Cincinnati

This paper describes how the physics undergraduate advanced labs are handled during Fall 2020 in a covid-19 pandemic situation. There were 24 students enrolled in the class. Students were divided into two groups, three activities, four blocks of time, and a lab "sparring" partner. The advanced labs have a three-prong approach with each student performing one computational exercise, one socially distanced in-person standard lab, and a home-based project. Ipython/Jupyter Notebooks, Matlab was used for computational labs. The in-person labs were set up in four rooms of two different buildings to follow social distancing safety protocols. About 18 different home-based projects were "built" and analyzed by 24 students. Online weekly logbook reports were introduced for easy access and feedback. The advanced lab was highly successful with great student participation, engagement, learning with more than expected positive outcomes.

Plenary III – James Stith, Vice President Emeritus American Institute of Physics, Diversity, Equity, and Inclusion: An Elusive Goal?, 2:30–3:30 p.m.

Session B2: Introductory Courses II

Saturday, Jan. 8, 3:30–4:30 p.m.

Moderator: TBA

Sponsor: AAPT

B2-01 - 3:30 p.m. | Contributed | Incorporating Mastery Grading into Astronomy 101

Presenting Author: Nicole Gugliucci, ngugliucci@anselm.edu

Standards-based grading refers to a number of assessment techniques that center the learning objectives of a course and the students' ability to perform to these standards. Mastery-based grading promotes deep learning and a growth mindset by grading each standard on an "all or nothing" approach with multiple chances for redos and revisions. In this scheme, student course grades are not determined by traditional tests but by how many learning objectives they have mastered by the end of the course. In this session, I will describe how a Mastery Grading scheme was implemented for the first time in the Introduction to Astronomy course at Saint Anselm College and reflect on student experiences and progress with this form of assessment. This course fulfills certain college learning objectives for science reasoning, and I will show how the assessment strategies directly line up with these college-wide goals.

B2-03 - 3:50 p.m. | Contributed | Expansion of the Universe: An OER Approach to Hubble's Constant

Presenting Author: R. Foster, Chattanooga State Community College

Additional Author | Ryen Lapham, Chattanooga State Community College

One advantage of using Open Education Resources is increased flexibility in pedagogical strategies. If learning materials are restricted to publisher-derived content, instructors are forced to model their teaching methodologies around those resources. Thus, instructors are unable to utilize alternative resources if they "compete" with publisher content or would overwhelm students. This is especially true with respect to institutions that standardize content across course sections, and any deviation is considered inappropriate. OER allows instructors at community colleges to tailor learning materials to the local demographics and state-wide observations. This project's OER laboratories will allow faculty to choose and customize their learning materials. Many of Chattanooga State's students are from traditionally underrepresented backgrounds (e.g. Pell-eligible, minority race, non-traditional/returning students, and academically underprepared), many introductory astronomy students will benefit from decreased course costs. This presentation is our flagship laboratory on Expansion of the Universe and utilizes coding, spectroscopy and mathematical methods. Laboratory copyright: Stephen Tuttle: Distant Nature

C6-POS-01 - 3:30 p.m. | Poster | An Optics Bench for Geometric Optics Experiments on a Budget

Presenting Author: Sandra Penny, Russell Sage College

Geometric Optics labs are a staple of many undergraduate physics labs. A simple but effective optics bench was developed to distribute for at-home optics labs during Spring 2020 and Spring 2021. The materials for the lab included three 38mm lenses (one concave, two convex), a PVC coupling, play-doh, used holiday light bulbs, and a few other common household items. The total cost for each set-up was only \$10 - \$15, making this a great option when the cost of a full optics bench is not feasible. These at-home experiments were just as effective as in-person versions used in previous years. In this poster, a full description of the lab set-up is described.

C6-POS-02 - 3:40 p.m. | Poster | Science 100 – Designed for Smaller Schools and Adult Education

Presenting Author: Donald Franklin, Retired/ consult with Openstax.college

Science 100 is a free to download ebook from Openstax.college. It is designed to expose all high school students to all of the Sciences. Using Energy as the central theme, the students are exposed to all sciences instead of having Science classes on each Science. This can also be used to prepared older students who are entering college so they can develop a knowledge of all sciences.

C6-POS-03 - 3:50 p.m. | Poster | Using Desmos to Visualize Fermat's Principle of Least Time

Presenting Author: Roberto Salgado, Minnesota State University Moorhead

I describe the sequential development of an interactive Desmos visualization of Fermat's Principle of Least Time. Upon applying the principle by a manual search and by a Desmos calculation, we numerically verify Snell's Law of Refraction and the Law of Reflection. I feel this helps make this abstract physical concept more accessible to students. Along the way, I will share some Desmos tricks that I learned in the process of creating such visualizations.*

*My Desmos file for Visualizing the Fermat Principle of Least Time can be viewed at <https://www.desmos.com/calculator/smyud6zwdg>

C6-POS-04 - 4:00 p.m. | Poster | Particle Physics Playground: Engage with Real Data Online Using Python

Presenting Author: Matthew Bellis, Siena College

Additional Author | Gabriella Tamayo, Siena College

Since 2014, I have worked with students at Siena College to develop and maintain a website, Particle Physics Playground, that shares simplified datasets from real experiments with teachers and students alike. Python is the preferred way of accessing these data and Jupyter notebooks, hosted on Google's Colab platform, allow users to get up and running seconds. These exercises have been used at the high-school and college level, both for classroom education and training of new research students, both at Siena and elsewhere. Students can learn about relativistic kinematics through hands-on activities, while developing their python programming skills. This poster will give an overview of the website content as well as future plans.

C6-POS-05 - 4:10 p.m. | Poster | Leveraging a Community of Learners to Envision Engaging Instructional Spaces

Presenting Author: Mel Sabella, Chicago State University

Additional Author | Boluwatife Akinwande, Christopher Chaney, ArChala Cohens, Ria Daniels, Alexis Dew, Nisrekh Khawaled, Mya Powers-Nash, Andrew Stephens, Andrea Van Duzor and Mel Sabella, Chicago State University

The Learning Assistant (LA) Model leverages undergraduate students (LAs) as facilitators of learning. LAs work with instructors and are often in positions where they collaborate with instructors on instructional material development and implementation. LAs often have complementary expertise on the types of technology that their peers use to engage in social and academic settings. This semester, eight Catalyst Emerging Leaders, who are experienced LAs, are advising CSU faculty on how we can better support students in our classes. This work leverages what we have learned since Spring 20, what we are learning in Fall 21, with a vision toward future instructional innovations.*

*Funded by The Partnership for College Completion, the Department of Education, and the National Science Foundation DUE# 1524829, 1911341.

C6-POS-06 - 4:20 p.m. | Poster | Artificial Intelligence laboratories for Medical Imaging

Presenting Author: Peter Riley, Deakin University

Laboratory explorations with Deep Neural Networks are introduced in the 4th year of the Medical Imaging course at Deakin University. These exercises will undertake lesion detection and classification in multiple modalities. The resources are modest, employing the accessible Mathematica front-end and running on GPUs operating at ~1 TFlops (FP32).

B4.1.1-01 - 3:30 p.m. | Contributed | Multilayer Network Analysis of the Force Concept Inventory

Presenting Author: Christopher Wheatley, West Virginia University

Additional Author | John Stewart, West Virginia University

Additional Author | James Wells

Modified Module Analysis using partial correlations (MMA-P) has proven to be a productive method for studying conceptual inventories. MMA-P can be used to analyze large datasets by forming networks of responses then using community detection algorithms to identify sets of responses that are consistently selected together. MMA-P can be extended by using multilayer network analysis. A multilayer network was constructed with pretest and post-test Force Concept Inventory (FCI) responses from five different institutions using samples ranging from N=10,000 to N=200. Each layer of the multiplex network was represented by a network made from the application of MMA-P to data from each institution. Within each layer, MMA-P finds communities of popular responses. Network comparison methods were then used to understand the similarities and differences between the sets of nodes and communities in the networks. This provides insight into the generality of previously identified properties of the FCI between institutions.

B4.1.1-04 - 3:50 p.m. | Contributed | Characterizing the Interaction Networks of Physics Students During Remote Teaching

Presenting Author: Meagan Sundstrom, Cornell University

Additional Author | Andy Schang, Cornell University

Additional Author | Natasha G. Holmes, Cornell University

Social network analysis (SNA) has gained popularity as a methodology for understanding patterns of student interactions. Such techniques have been applied extensively to face-to-face but not remote physics courses. To bridge this gap, we surveyed students in four remote introductory physics courses, asking them to report peers with whom they meaningfully interact about the course. We then applied SNA methods to determine how various factors relate to the observed network formations. We find differences in what course content students discuss with peers in their lab and discussion sections. Students with higher final course grades were more connected to their peers in interaction networks related to lecture but not lab content. We also discern several trends between students' gender and their network position, but no strong patterns with regard to students' race/ethnicity. Results suggest that group-forming surveys may be useful tools for instructors to create comfortable social environments for students.

B4.1.1-05 - 4:00 p.m. | Contributed | Factors Related to Rural and First-Generation Persistence in Engineering

Presenting Author: John Stewart, West Virginia University

Additional Author | Elaine Christman, West Virginia University

This study examined the relationship between attending secondary school in a rural locale, first-generation college student status, and persistence in engineering majors at West Virginia's state flagship university. Students who are rural or first-generation depart engineering by changing majors and by leaving the institution without degrees at higher rates than other students, and patterns of attrition for these students are qualitatively different. High school preparation was a significant predictor of leaving college after the freshmen year with rural and first-generation students at higher risk correcting for high school preparation; however, neither rurality nor first-generation status were significant predictors of continuing in engineering to the sophomore year after controlling for students' high school academic preparation.

B4.1.1-02 - 3:40 p.m. | Contributed | Investigating Students' Self-Efficacy Using Mixed Methods Research

Presenting Author: Carissa Myers, Michigan State University

Additional Author | Vashti Sawtelle, Lyman Briggs College & Department of Physics & Astronomy Michigan State University

Additional Author | Rachel Henderson, Department of Physics & Astronomy & CREATE for STEM Institute Michigan State University

Research on self-efficacy -- or the confidence in one's capability to perform a task -- has been shown to predict achievement and persistence in the sciences. Over time, students' experiences in curricular and/or co-curricular activities may threaten their self-efficacy. To investigate the threats or supports to students' self-efficacy, we are using a mixed methods approach to collect in-the-moment information about lived experiences. This novel design creates a conversation between the Experience Sampling Method, a quantitative technique using surveys of domain-specific self-efficacy, and daily reflections, a qualitative technique investigating threats and supports toward students' self-efficacy. Thus, we can build a holistic narrative of which curricular and/or co-curricular activities are affecting a student's self-efficacy as well as how and why these activities may be affecting their self-efficacy. Through the lens of one student, we will show how the research design is investigating self-efficacy through the conversation between the ESM and daily reflections.

B4.1.1-06 - 4:10 p.m. | Contributed | Inclusion and Training Needs in a Physics Learning Assistant Program

Presenting Author: Sujata Krishna, University of Florida

Additional Author | Pavlo Antonenko, University of Florida

Additional Author | Ellen Christine Davis, University of Florida

Additional Author | May Mansy, University of Florida

Additional Author | Julie Brown, University of Florida

We will report on the equity and inclusion issues identified in a set of active learning algebra-based physics classrooms using learning assistants to facilitate small group problem solving. The value of equity and representation has been clear for some time, but the changes necessary to enable it have been slow to unfold. We will report on what has been done to address this at the University of Florida Physics LA program and what unexpected issues have emerged in the process. We will address the need for training of learning assistants in diversity and inclusion will be and touch upon the lesson plans that are being developed and piloted for this purpose.

Session B5.1: PER: Student and Instructor Support & Professional Development, Program and Institutional Change

Saturday, Jan. 8, 3:30–4:30 p.m. Moderator: TBA Sponsor: Committee on Research in Physics Education

B5.1-01 - 3:30 p.m. | Contributed | Balancing Consistency and Authenticity: Lessons Learned Designing Reformed Curricular Materials

Presenting Author: Joshua Rutberg, Rutgers University - Newark

Additional Author | Sheehan Ahmed, Rutgers University - Newark

Additional Author | Diane Jammula, Rutgers University - Newark

Additional Author | Patrick Makowski, Fairleigh Dickinson University

Since Fall 2019, our team has been in the process of reforming our introductory physics courses using the Investigative Science Learning Environment (ISLE) approach. This, alongside the pandemic which required all courses to be held entirely online for one year, has required us to revise our curricular materials multiple times over the past several years. In this talk we will share some of the strategies we have learned both for developing materials which encourage students to actively participate in their own learning and for creating materials which can be used authentically by any member of the teaching team.

B5.1-02 - 3:40 p.m. | Contributed | Improving Out-Of-Field Preparation for High School Physics Teachers

Presenting Author: Carlee Garrett

Additional Author | Jonathan Perry

Additional Author | Dawson Nodurft

Additional Author | Tatiana Erukhimova

The well documented deficit of physics graduates pursuing education as a career has led to a significant number of high school teachers with little to no background in the discipline, which can result in reduced impact in the classroom. The Mitchell Institute Physics Enhancement Program (MIPEP) was founded in 2012 to address such problems through targeting out-of-field high school physics teachers. MIPEP participants work with Texas A&M University faculty and two master teachers over a two week period, focusing on both subject comprehension and pedagogy for implementation. Here we examine the impact of the virtual version of MIPEP on the 2021 cohort. Participant pre- and post-program knowledge and confidence were measured using an assessment compiled of questions from mechanics, electricity and magnetism, optics, and modern physics. Analysis of our data will be shown, which may encourage other institutions to create similar programs.

B5.1-03 - 3:50 p.m. | Contributed | Overcoming Student Resistance to Active Learning During an ISLE-based Reform

Presenting Author: Sheehan Ahmed, Rutgers University - Newark

Additional Author | Diane Jammula, Rutgers University - Newark

Additional Author | Patrick Makowski, Fairleigh Dickinson University

Additional Author | Joshua Rutberg, Rutgers University - Newark

Since Fall 2019 we have been reforming both our algebra and calculus-based introductory physics courses with the Investigative Science Learning Environment (ISLE) approach. As expected, each academic year, students are initially resistant to the approach. In this talk we will discuss specifics of the resistance to ISLE expressed by students in our calculus based introductory physics course and the quantitative effects of "pep talks" and institutional change sessions. We will also explore possible improvements to our implementation of the ISLE approach to mitigate resistance particularly from students who have already encountered non-ISLE physics.

B5.1-04 - 4:00 p.m. | Contributed | Comparing Perceived Explanation Quality Between Different Instructor Types

Presenting Author: Joe Olsen

Additional Author | Debbie Andres

Additional Author | Charles Ruggieri

Universities use instructors with varying levels of physics expertise for undergraduate physics instruction, including faculty members, graduate teaching assistants, and undergraduate learning assistants. This study examines the effects of instructor type on students' ratings of explanation quality. We collected written explanations to common introductory physics questions from highly recommended instructors of each type. Students enrolled in an introductory physics course made pairwise comparisons of the written explanations until a rank order could be generated for each student participant. We determined if instructor type could determine placement in a student's rank order using ordinal regression. Using a relative placement algorithm, we extracted a general rank order for the explanations that reflects consensus opinion on the relative quality of the explanations. We present the results as a commentary on the relative effectiveness of different instructor types on providing explanations that students perceive as good explanations.

B5.1-06 - 4:20 p.m. | Contributed | The New Normal: Three years into our ISLE-based reform

Presenting Author: Diane Jammula, Rutgers, Newark

Additional Author | Sheehan Ahmed, Rutgers, Newark

Additional Author | Patrick Makowski, Fairleigh Dickinson University

Additional Author | Joshua Rutberg, Rutgers, Newark

In Fall 2019 we reformed all of our introductory physics courses with the Investigative Science Learning Environment (ISLE) approach. In this approach, students build physics knowledge by doing science. We used ISLE-based materials to write a curriculum and have made structural changes to support it. The curriculum is taught by a team of 10 instructors (full time faculty, part time lecturers, and graduate TAs) with the help of 10 undergraduate Learning Assistants (LAs). All instructors and LAs attend a pre-semester workshop and weekly prep meetings. Three years into our reform, the curriculum and instructional team has become the "new normal." 450 students enroll in our courses each semester. The big goal driving our reform is to teach students to think like scientists. We present data showing success and areas of improvement.

Session C2: Physics Education Research Posters II

Saturday, Jan. 8, 3:30–4:30 p.m.

Moderator: TBA

Sponsor: Committee on Research in Physics Education

C2-POS-01 - 3:30 p.m. | Poster | Quantum Interactive Learning Tutorial on Larmor Precession of Spin

Presenting Author: Chandralekha Singh, University of Pittsburgh

Additional Author | Ben Brown, University of Pittsburgh

We conducted research on student difficulties and developed and evaluated 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 them integrate qualitative and quantitative understanding. Findings will be presented. We thank the National Science Foundation for support.

C2-POS-02 - 3:40 p.m. | Poster | Just-in-Time Teaching and Peer Instruction in Quantum Mechanics

Presenting Author: Chandralekha Singh, University of Pittsburgh

Additional Author | Ryan Sayer, Bemidji State University

Additional Author | Emily Marshman, CCAC

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.

C2-POS-03 - 3:50 p.m. | Poster | Quantum Interactive Learning Tutorial on Quantum Key Distribution

Presenting Author: Chandralekha Singh, University of Pittsburgh

Additional Author | Seth Thomas, Juniata College

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.

C2-POS-04 - 4:00 p.m. | Poster | Improving Student Understanding of Quantum Mechanical Observables and Operators

Presenting Author: Chandralekha Singh, University of Pittsburgh

Additional Author | Emily Marshman, CCAC

In quantum mechanics, representations of quantum operators in the position or momentum representation is an important concept for students to learn. However, many students have difficulties writing operators in the position and momentum representations. We investigated student difficulties with quantum operators in the position or momentum representation in the context of Dirac notation so that we can use them to develop learning tools such as a Quantum Interactive Learning Tutorial (QuILT) to help students develop a robust understanding of these concepts. Here we describe the investigation of student difficulties. We thank the National Science Foundation for support.

C2-POS-05 - 4:10 p.m. | Poster | Impact of Supplemental Resources on Student Outcomes in Introductory E&M

Presenting Author: Nathan Valadez, Texas A&M University

Additional Author | Tatiana Erukhimova, Texas A&M University

Additional Author | Jonathan Perry, University of Texas

Additional Author | Dawson Nodurft, Texas A&M University

Additional Author | Carlee Garrett, Texas A&M University

Calculus-based introductory physics classes are prerequisite courses for many STEM majors and traditionally have a large attrition rate. One way to improve student learning outcomes is by creating open access supplemental materials. In this study, we investigated the relation between use of supplemental materials and student performance in a calculus-based introductory electromagnetism course. The resources examined in this study included video resources, summarizing important concepts, showing example problems, and covering in-depth problem-solving techniques, as well as prior year's exams. We analyzed student scores from the Brief Electricity and Magnetism Assessment, exam scores, and student responses to anonymous surveys. We will present results of student performance for more than 600 students enrolled in a fall 2021 semester based on their use of available supplemental resources.

Session C4: Physics Education Research Posters III

Saturday, Jan. 8, 3:30–4:30 p.m.

Moderator: TBA

Sponsor: AAPT

C4-POS-01 - 3:30 p.m. | Poster | Refining an Intervention to Prompt Reflective Thinking

Presenting Author: John Kelly, Tennessee State University

Dual Process Theories of Reasoning (DPTOR) state that cognition has two major processes: a fast, automatic process (heuristic) and a slow, reflective process (analytic). Many introductory physics students use the heuristic that acceleration and velocity are the same thing. In a Conceptual Physics class, multiple choice questions on free fall were preceded by multiple choice "check" questions - one on forces in free fall, and one on Newton's 2nd Law. This work refines a pilot study using more complex knowledge statements. That data suggested that the inclusion of the knowledge statements served as a productive intervention for engaging the analytic process, but the pattern of answers suggested that the knowledge statements were ambiguous. Student responses to check questions were more consistent than knowledge statements with similar performance on the free-fall questions. 80% of the students who answered the check questions correctly also answered all the free-fall questions correctly.

C4-POS-02 - 3:40 p.m. | Poster | Inspiring Physics Education Researchers in Disability Education Research

Presenting Author: Rebecca Rosenblatt, NSF/EHR/HRD

Additional Author | Rebecca Lindell, Tiliadal STEM Education: Solutions for Higher Education

Since 2015, more than 19% of undergraduate students enrolled in higher education report having a disability. In addition, searches of both the NSF public award data and other discipline based education research (DBER) publications makes it clear that disability education research has been a thriving research area for several years. However, despite the clear need for this research, available funding, and a record of important discoveries from other DBER fields. There is surprisingly little physics education research (PER) on any aspect of disability education. Of the 400 plus articles published by Physical Review - Physics Education Research since 2010, less than 10 articles mention disability, deafness, blindness or autism and only 5 clearly center this in their work. In this presentation, we will examine a variety of data designed to illustrate the importance of disability education research and stimulate PER interest in this important field of study.

C4-POS-03 - 3:50 p.m. | Poster | Learning Process Acceleration by Means of Supplementary Courses and Problems

Presenting Author: Tamas G. Orosz, ELTE - Eötvös Loránd University

Sometimes it is important to accelerate the learning process due to different reasons, such as preparing for exams or contests. A classroom curriculum is usually well defined, and all the relevant upcoming steps are foreseen. However, supplementary learning materials can be useful and important to cover missing knowledge. A new approach is applied to support the understanding of physics problem solutions. Complex physics problems are divided into some elements where corresponding theoretical concepts and elementary physics problems can be opened. This way students can obtain necessary theoretical knowledge more easily and get solid basic knowledge as well by solving relevant elementary problems. It is found that besides learning physics in a systematic way, connecting relevant knowledge to practical problems considerably accelerates learning process, and makes it more effective as well.

C4-POS-04 - 4:00 p.m. | Poster | Graphic Design for a Physics-Education Board Game

*Presenting Author: Abigail Huffman, * Siena College*

Additional Author | Matthew Bellis, Siena College

Additional Author | Germaine Gatewood, Siena College

We developed a board game that incorporates the rules of quantum mechanics into the game play. The goal was to create a fun and effective pedagogical instrument that could be used at the high-school or introductory college level, or even sold to the general public. Because we knew we are competing against any number of distractions and entertainment options, we wanted the game to be as professional looking and visually engaging as any game on store shelves. In this poster, I will walk you through the process of developing a consistent design style for the entire game, and then balancing artistic vision and scientific accuracy.

*Sponsored by Matt Bellis (additional author).

C4-POS-05 - 4:10 p.m. | Poster | Renewable Energy-based Physics Outreach Events During the Covid Pandemic

Presenting Author: Roberto Ramos, University of the Sciences

The COVID pandemic has significantly impacted the way physics educators conduct educational outreach. In this presentation, I will present my experience with designing, planning and executing informal science learning events under the theme of renewable energies during the pandemic. From two week-long virtual summer camps, I describe the challenges and successes that we experienced, and the lessons learned. Held online via Zoom, the two week-long camps had participants from diverse communities who were introduced to renewable energy and performed hands-on experiments using solar cells, project-building by building and testing solar cars, and solar boats, and hands-on optics experiments. For engagement, campers received a free kit - which we found indispensable, consisting of a digital multimeter and materials

for projects and experiments. Other events include face-to-face outreach to high school students with theme of solar energy. I will report on the outcomes of these events and the feedback from participants.*

*R. Ramos acknowledges the support of Constellation - an Exelon company and Puratos Corporation.

Session: Professional Skills for Students Saturday, Jan. 8, 3:30–4:30 p.m. Moderator: Devyn Shafer

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

No abstracts.

Session C5: SPS Undergraduate Poster Session Saturday, Jan. 8, 3:30–4:30 p.m. Moderator: TBA

Sponsor: AAPT

C5-POS-01 - 3:30 p.m. | Poster | Incorporating Open-Source Materials in Learning and Teaching about Climate Change

Presenting Author: Emily van Zee, Oregon State University

Additional Author | Elizabeth Gire, Oregon State University

Additional Author | Kelby Hahn, Oregon State University

Exploring Physical Phenomena: What Happens When Light from the Sun Shines on the Earth? is an open-source textbook for courses for prospective teachers. After exploring light and thermal phenomena, students consider the influence of such phenomena on local weather and global climate change. In addition to explorations with everyday materials, they access Internet resources such as the University of Colorado's Phet simulation of the greenhouse effect, vivid data presentations such as NASA's model of increasing global temperatures from 1884 onward, examples of impact such as Climate Central's predictions for rising sea levels at particular locations, and local, state, national, and international efforts to address global climate change issues such as the Summary for Policy Makers by the Intergovernmental Panel on Climate Change. Students also explore their carbon footprints and other ways individuals can take action. Excerpts can provide resources for outreach activities, short courses, and webinars about climate change.

C5-POS-02 - 3:40 p.m. | Poster | A Low-Cost Data Acquisition Solution for Undergraduate Physics Laboratories

Presenting Author: Jeremy Long, Southwest Baptist University

Additional Author | Perry A Tompkins, Southwest Baptist University, Retired

The National Instruments USB-6210 Data-Acquisition interface is very useful as a nexus in computer-based undergraduate physics laboratories. Our project was to design an interface, the SBU Physics Instrumented Learning Laboratory, or SPILL box to encapsulate this unit while keeping a low cost for educators and users. Our design can capture data from various inputs, provide excitation and display it in lab programs such as LabVIEW. Each lab has been programed to use the inputs to gather desired data and distribute them to user desired outputs. With the addition of a proto board on top of the unit, and access to all of the interfaces' signals the lab diversity for this SPILL box can handle a wide range of concepts studied in the physics lab and a perfect fit for educators desiring a flexible, low cost solution to computer-based laboratories.

C5-POS-03 - 3:50 p.m. | Poster | Trends Seen In an Introductory Astronomy Course Graded on Participation

Presenting Author: Harshini Sunil, University of Colorado, Boulder

Additional Author | Jennifer Blue, Miami University

This research focuses on data collected from Canvas on grades, participation, page views and student activity with the course material from one synchronous section and one asynchronous section of an introductory astronomy course. The course was participation based with chapter quizzes, tutorials, tutorial quizzes and written assignments. No exams were given. The analysis of the correlation between participation per week and grades per week was made, showing that engagement with the course material and canvas did not impact grades. There was no established relationship made. Students that interacted the most or the least, still received grades that were scattered. For the synchronous and asynchronous sections, as the semester progressed, the average page views decreased. However, when studying the average participation per week, the synchronous class had no specific correlation but the asynchronous section had a steady, linear increase.

C5-POS-04 - 4:00 p.m. | Poster | Study on Attainment of Learning Objectives and Practical Effects in Introductory Physics Course

Presenting Author: SHI-HONG MA, Department of Physics, Fudan University

Additional Author | YONG-XIN CHEN, Department of Physics, Fudan University

Educational evaluation is of great importance to teaching and the development of students. This paper will give some testees a survey of college physics-optics, using 2PL and 3PL of Item Response Theory to analyze and providing thoughts on optimizing the system of learning and teaching. The result shows that advanced ability oriented questions fit well with inspecting and ability building, and fill-in-the-blank test has a higher priority over multiple-choice question. Students are commonly short of advanced ability, and they should focus on the development of intermediate ability and make progress steadily. Teachers should pay attention to complex concepts, trying to lead students and innovate teaching method. Students should emphasize habit training and develop correct overlooks on the world, life and values.

C5-POS-06 - 4:20 p.m. | Poster | Simulations of Shoulder and Arm

Presenting Author: Jee Woo Kim, University of Hartford

Additional Author | Dan Liu, University of Hartford

The arm and shoulder is a major part of the body, but unfortunately, not a lot of related simulations are available. Through GeoGebra, we developed an interactive simulation of forces of a human arm and shoulder—which these force vectors include the muscle of the bicep and deltoid, and the forces on the shoulder and elbow joints. This simulation helps us understand Newton's Second Law and the concepts of torque and equilibrium as a learning tool, which can be used in physics classrooms. With further development, this simulation has the potential to be implemented in hospitals and in sports science.

C5-POS-05 - 4:10 p.m. | Poster | An Intuitive Way to Understand Curved Spacetime

Presenting Author: Jose Mazzini, nn

The standard view is that space and time act together, putting aside the energetic component, leaving STR to valid paradoxes over it. GTR clears this up and deals, inclusive, with accelerated frames of reference, where energy acting over spacetime is the essential part of the GTR equations. Still, the primary attention is over, the challenge to imagine Minkowski's 4-dimensional spacetime. Their representations commonly express a curved space & time consequence of energy over spacetime instead from its origins, the equivalent moving space by the presence of proper energy and surrounding ones.