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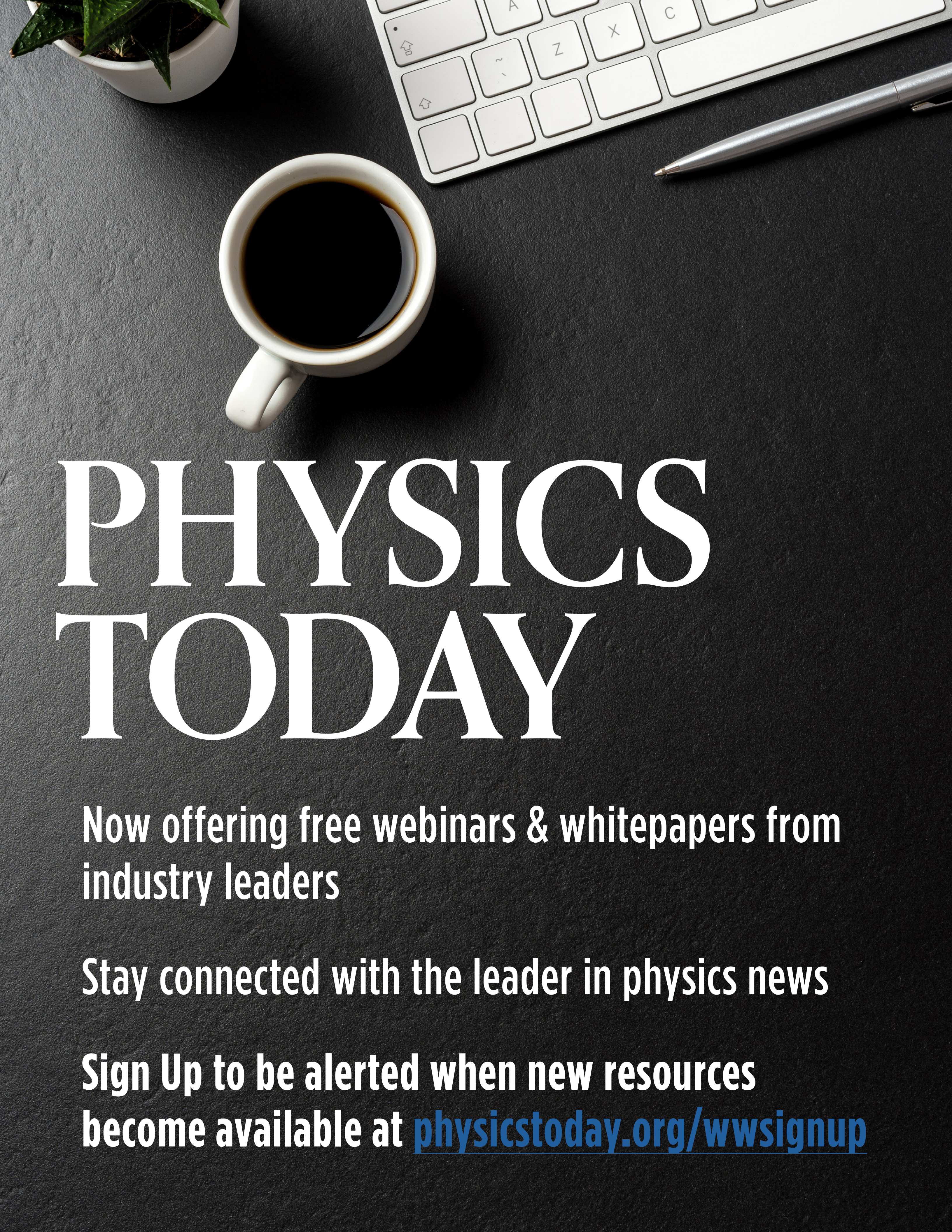
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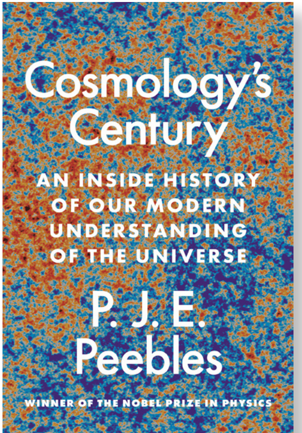

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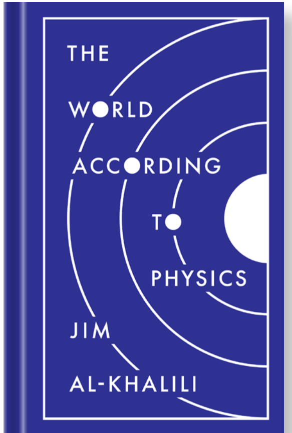

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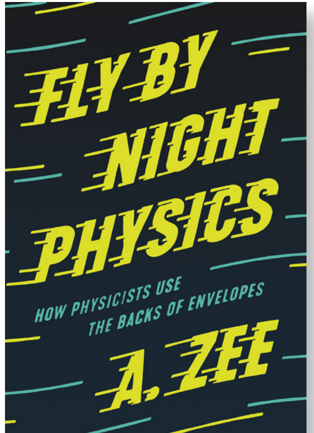

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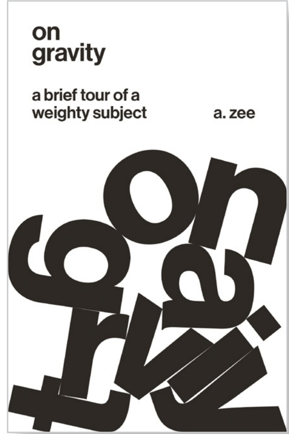

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January 10, 2021 2:30 PM - 3:45 PM

JANUARY 11, 2021 | 10:30 AM - 11:45 AM

JANUARY 11, 2021 | 1:30 PM - 2:45 PM

January 12, 2021 | 11:30 AM - 12:45 PM

A1.01 | 21st Century Physics in the Physics Classroom

JANUARY 9, 2021 | 12:00 PM - 1:15 PM

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A1.1-01 | Virtual Medical Physics Undergraduate Laboratory Experience with Linear Accelerator Data

Presenting Author | *Sukhjit Kaur, Northwest Medical Physics Center*
Additional Author | *Jessica Firestorm, Northwest Medical Physics Center*

Hands-on experience is of utmost importance to physics laboratory experiences. Like most other schools and colleges, classes at Central Washington University had to adjust quickly to online-learning setups this past quarter. This new teaching style unfortunately pushed aside in-person interactive laboratory sessions that could have been used to supplement lecture-style videos that students watched as a part of their introductory medical physics seminar. Utilizing pre-measured data, videos, and photographs from a live clinical linear accelerator, the team at Northwest Medical Physics Center was able to create an online laboratory experience for real-time student engagement. In this presentation, the method of implementation of the lab will be discussed, along with goals for future expansion of the virtual medical physics lab program.

A1.1-02 | Teaching Science with Hands-on Diagrams

Presenting Author | *George Kontokostas, National and Kapodistrian University of Athens*

This educational research is about teaching electromagnetic interaction or rock formation. We use papers showing the elementary electron-electron-photon Feynman diagrams or sentimentation-metamorphism-melting geo-diagrams. The individual papers could be rotated, inverted, and combined to provide diagrams for any electromagnetic interaction process or rock formation. Combining orientations of single paper, we make combinations of three or more papers. Time is running vertically upward in every diagram. Given the opportunity to manipulate the papers, students became involved and rapidly developed understanding of electromagnetic interaction or rock formation. The students did strikingly better on the post-tests than the pre-tests.

A1.1-03 | Gravitational Wave Science for the Secondary Classroom: Discoveries and Activities

Presenting Authors | *Charlie Payne, North Carolina School of Science and Mathematics, Jackie Blondell, ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav) Swinburne University of Technology (Australia)*

2020 has seen a release of multiple exciting new results in gravitational wave science! In this session, we will review these latest discoveries that have opened new windows into understanding the universe. Then we will introduce teachers to activities that can be used in the classroom, both remote and in-person, to introduce secondary science students to some of the major concepts related to understanding and detecting gravitational waves, including the new results! Detectors such as LIGO and Virgo will be examined, as well as the use of Multimessage Astronomy.

A1.1-04 | Re-development in Physics Experiment Teaching Using Simulation Based on PhET

Presenting Authors | *Ma Ying, School of Physics and Materials Science, Guangzhou University, Xie jing Hong, School of Physics and Materials Science, Guangzhou University*

Virtual or simulating experiments are developed and introduced by many organizations to enrich physics experiments within and beyond classrooms. Yet in the rural areas where resources are limits both physics experiment instruments and internet connection, teachers find it difficult to integrate experiments into classroom teaching activities. We analyzed the roles and current situations of simulating experiments in high school physics teaching in China. Evaluated several current running physics experiment simulation software packages. We found PhET is suitable for redeveloping and integrating into an off-line running package, which will benefit experiment teaching in rural areas where internet coverage is poor. The paper presents the approaches of redeveloping. For the sake of generality, we use Java language and HTML language for programming, and use HTML5 technique to integrate the experiments into an off-line running package. Successful on-the-site running shows the feasibility and applicability of redeveloping PhET simulation experiment for physics experiment teaching.

A1.1-05 Shaping Light in Time and Space

***Presenting Author* |** *Gabriel Spalding, Illinois Wesleyan University*

Partnerships between our professional organizations and manufacturers are making it much more affordable to bring spatial light modulators (SLMs) into undergraduates' hands. SLMs are one way to shape light, in space or in time, making possible programmable dynamic holograms that actually have corporeal substance, and can play a role in faster-than-light imaging, as well as the use of entangled photon pairs (which cannot really be described as individual particles), such that the photons incident upon the detecting camera have never interacted with the object successfully imaged(which is called "ghost imaging," in reference to Einstein's concern over "spooky action at a distance"); this "spooky" result is achieved by exploiting correlations that are required by conservation of energy & momentum. —Observed phenomena of these sorts prompt students to revise their mental model of what a "particle" is!

A1.02 | Effective Practices in Educational Technology

January 9, 2021 | 12:00 PM - 1:15 PM

Sponsor: *Committee on Educational Technologies*

A1.2-01 | Mechanism of a Water Drinking Bird, Thermodynamics and Irreversible Thermodynamics

***Presenting Author* |** *Hiroshi Ulchi, Osaka Gakuin University*
Additional Author | *Lisa Ulchi, University of California, Los Angeles*
Additional Author | *Schun Uechi T, KPMG Ignition Tokyo. Data Tech*

A drinking bird (DB) also known as dunking bird or dipping bird is an interesting and amusing toy, swinging back-and-forth like a simple pendulum. But the drinking bird is an excellent experimental toy for thermodynamics in physics. The field of thermodynamics explains about mechanism of work, heat and energy, temperature, pressure and volume. These quantities are working in everywhere in nature, our daily life, engineering technologies, etc., and a drinking bird is often called a heat engine. It changes heat flows into work very efficiently. So, the drinking bird makes a perfect experimental device for understanding theory of heat and energy (thermodynamics). DB’s mechanical and thermomechanical motion can explain theories and laws of thermodynamics and irreversible thermodynamics.

A1.2-02 | Harness the Power of the Classroom for Data Collection

Presenting Author **|** *Christian Gehman, Trinity Valley School*

Transform a classroom lesson into a powerful cooperative data collection activity by using online video (typically ones from YouTube with telemetry data) along with a shareable spreadsheet. Students analyze sections of the video and input their answers into the spreadsheet, allowing for processing of a lot of data in a short amount of time. Students go from concept introduction to data collection to data analysis in very short order, making for an interactive and dynamic lesson.

A1.2-03 | Sensing and Representing Magnetic Fields in Augmented Reality

Presenting Author **|** *Aakash Kumar, Teachers College, Columbia University*
Additional Author | *Colleen Megowan-Romanowicz, American Modeling Teachers Association*
Additional Author | *Mina Johnson-Glenberg, Arizona State University*

Many concepts in physics involve abstract ideas that require learners to imagine invisible causes, while interpreting the concrete effects and integrating seemingly ambiguous representations (ERs). The difficulty of this parallel processing often results in learners developing misconceptions and lacking the skills to communicate about these concepts effectively. This paper describes a study that used an augmented reality program (Magna-AR) to help learners see abstract magnetic fields within a real-world environment using the internal magnetic field sensor within mobile devices. Learners were asked to use Magna-AR to construct 3D visualizations of magnetic fields of the Earth and around other smaller magnets. Learners were also asked to draw 2D visualizations of magnetic fields and to identify the connections between various ERs of magnetic fields. A selected subset of the learners also participated in follow-up interviews. Preliminary analyses of these data will be discussed.

A1.2-05 | On Creating Your Own Course Videos to Emulate Group Work

Presenting Author **|** *Steven Maier, Northwestern Oklahoma State University*

For highly interactive courses regularly using lab equipment, the transition to remote instruction presents significant challenges. Breakout rooms during video conferences can be quite helpful for discussion, but without shared experiences with equipment, it's not quite complete. And, while there exist many videos and resources online, there are likely details or more salient points you'd like students to consider than what's readily available from the publisher or on the internet. This talk will present lessons learned in creating amateur videos of mock group-work as an attempt to keep the flow and atmosphere of a studio-format class constructive. This is part of a series of talks stemming from the NextGen PET FOLC project. This work was supported by the National Science Foundation grant NSF DUE-1626496.

A1.2-06 | Modeling-Based, Technology-Enhanced Curriculum for Early Childhood Physics Education

Presenting Authors **|** *Krista Hook, Purdue University; Hector Will, Pinto E. Purdue University*
Additional Author **|** *Lynn Bryan A, Purdue University*
Additional Author **|** *Ala Samarapungavan, Purdue University*
Additional Author **|** *Carolyn Staudt, Concord Consortium*

A paucity of research exists which systematically uses a model-based inquiry framework to explore early childhood learning that focuses on concepts of matter, its changes, and the effective use of technology in early physics learning. To this end, we share our efforts to develop a cognitively grounded, research-based curriculum through which we examine early physics learning on the states of matter and its changes. In six intervention classrooms, kindergarteners articulated their emerging models of matter as they engaged in an inquiry-based, modeling-based, technology-enhanced curriculum on states of matter. In comparison, four classrooms implemented school-based science curricula. Technology tools included a simulation application to observe/analyze dynamic models of the particle nature of matter and model-building tool for states of matter and its changes. We found that kindergarteners from intervention classrooms showed significant gains in learning and were successful in shifting from macroscopic models to simple particle-based models of matter.

A1.03 | (A1.03) My Favorite Vernier Product

January 9, 2021 | 12:00 PM - 1:15 PM

Sponsor: *Committee on the Interests of Senior Physicists*

A1.3-01 | Vernier and My Classroom

Presenting Author **|** *Dwain Desbien, Estrella Mountain Community College*

Vernier products have greatly changed how my classroom and lab is run. I have designed my classroom around student access to Vernier probe ware so that lab can occur at any time! In this talk I will discuss how I use some of my favorite products in class and online (I mean COVID and all). I will highlight the products that in my opinion have impacted student learning the greatest. This will include everything from motion to atomic spectra!

A1.3-02 | “Retired, Rehired, Reloaded with Vernier”

Presenting Author **|** *Todd Leif, Bennington High School*

After a 30-year physics teaching position at Cloud County Community College in Concordia, KS I retired on the last day of July 2020. Three days of fishing and I went back to work. This time at Bennington, Nebraska, as a High School Physics and Chemistry Instructor. Who were the first people I called once I moved into my new school? Vernier Software, my go to, my clutch performers, my other right hand. From Graphical Analysis to Pivot Interactives Vernier has always been beside me in my career. This talk will be historical, and futuristic, ultimately leading to my newest favorite Vernier product, Pivot Interactives.

A1.3-03 | No Equipment, No Problem

Presenting Author **|** *Karen Matsler, UT Arlington*

Whether instruction is in a face-to-face classroom or virtual, Video Analysis allows students to identify physics in the world around them while collecting some real data. Students don't need any equipment to learn physics and if you teach secondary physics, you know how important it is for students to journal. Vernier's Go Direct Technology allows for real time data collection and partners with Science Journal. This session will give examples of how both of these have been used in classrooms to enhance student understanding.

A1.4-01 | | Initial Implementation of an Upper-Division Thermal Physics Assessment

Presenting Author **|** *Katherine Rainey, University of Colorado Boulder*
Additional Author | *Michael Vignal, University of Colorado Boulder*
Additional Author | *Bethany Wilcox, University of Colorado Boulder*

Thermal physics encompasses thermodynamics and statistical mechanics content and is a core upper-division course requirement for most physics' degrees. Thus, in order to improve student outcomes in these courses, it is important for both educators and researchers to have a validated method of evaluating student understanding of upper-division thermal physics content. For an assessment like this to be useful, it is crucial that the assessment tool can be easily implemented, easily scored, and provide insightful feedback. In this presentation, we discuss a multiple-response upper-division thermal physics assessment that was distributed in an online format. Initial validation results, average student performance, and feedback for instructors will be discussed.

A1.4-02 | Designing Research-based Assessment Feedback for Instructors

Presenting Author **|** *Amali Priyanka Jambuge, Kansas State University*
Additional Author | *James Laverty T, Kansas State University*
Additional Author | *Bethany Wilcox, University of Colorado Boulder*
Additional Author | *Katherine Rainey, University of Colorado Boulder*

Assessment results provide valuable information about student learning. Accurately interpreting this information to modify courses is an essential step towards facilitating better student learning. Thus, as part of developing a standardized assessment for upper-division thermal physics, we design theory-based feedback for instructors in which they can trace how well their courses align with learning goals associated with scientific practices. This feedback provides instructors actionable information to operationalize scientific practices into their learning goals, thus encouraging not just content knowledge, but how to use that knowledge. In this talk, we lay out this feedback design process with specific examples from our data. This work highlights the importance of actionable feedback for instructors that facilitates explicit course modifications in physics classrooms.

A1.4-03 | Development of a Rubric to Analyze Student Teaching Assistants' PCK-Q

Presenting Author **|** *Beth Thacker, Texas Tech University*
Additional Author **|** *Stephanie Hart, Texas Tech University*
Additional Author **|** *Jianlan Wang, Texas Tech University*
Additional Author **|** *Kyle Wipfli, Texas Tech University*

We report on the development of a rubric designed to analyze pedagogical content knowledge in the context of questioning (PCK-Q). The rubric is based on five components of PCK-Q: Orientation, Knowledge of Curriculum, Knowledge of Students' Understanding, Knowledge of Instructional Strategies and Knowledge of Assessment (Magnusson, 1999). We are developing it to analyze 1) written responses to an instrument designed to measure PCK-Q and 2) video classroom observations of student assistants' (SAs') interactions with students. The classroom observations have first been coded by a coding scheme that analyzes levels of questioning and direct instruction in an inquiry-based classroom. We expect the strongest evidence of PCK-Q in video sequences of SAs using sequences of guided questions. Guided questions demonstrate evidence of instructor content knowledge, knowledge of students' understanding and knowledge of common student difficulties, while helping students evaluate experimental evidence, solve a problem or come to a correct conceptual understanding.

A1.4-04 | Fails for Concept Inventory (digital) Data Encoding

Presenting Author **|** *Florian Genz, Universität zu Köln / Germany*
Additional Author **|** *Kathleen Falconer, Universität zu Köln / Germany*
Additional Author **|** *André Bresges, Universität zu Köln / Germany*

This will be a humbling talk. We take you on our journey of fails in digital and analogue data collection, encoding and scoring as well as procedures and ideas of fixing them. We answer questions like: "How can I reach sufficient encoding redundancy?", "How to estimate the coding error probability?", "What are the pitfalls in (digital) data scoring?", "What metadata might become useful for my analysis? "Or as Springuel, Wittmann & Thompson (2019, p.2) would say: "[D]ata encoding is often neglected or taken for granted, even though this step forms an important bridge between the data collection and analysis."

A1.4-05 | Assessment after Screencast Feedback and Revision on Students' Own Scenarios

Presenting Author **|** *Nancy Beverly, Mercy College*

To provide an especially supportive environment for learning in the online and blended environment, screencast commentaries of student drafts of their own scenarios were given before student revisions were submitted and assessed. Screencast commentaries were done for several scenario submissions on the different physics concepts covered in the class and in digital practice. Doing their own scenarios can be challenging for students, so the screencasts were well received. The question is if they helped improve student competence in the learning outcomes of the course. A comparison to pre-pandemic courses is in progress.

A1.05 | Things We Will Keep from Remote Experiences in Teaching Physics Labs/Courses

January 9, 2021 | 12:00 PM - 1:15 PM

A1.5-01 | Making Choices for Virtual Labs in "The Science of Acoustics"

Presenting Author | *Timothy McCaskey, Columbia College Chicago*

Our course "The Science of Acoustics" is an introductory course on waves, oscillations, and sound. My colleagues and I have been teaching the lab portion in a consistent way over the past decade with only minor tweaks to equipment and instructions, but our switch to remote learning forced me to rethink some activities. This talk is about making choices concerning how to modify lab activities so students can achieve the relevant learning objectives. I may not have made "correct" choices in every case, but I will discuss thinking on labs that range from ones kept basically identical except for the use of virtual equipment (e.g., a pendulum lab) to others where the questions we asked were completely flipped around (e.g., a lab on standing waves). I will also reflect on how this experience will affect my delivery when things go "back to normal."

A1.5-02 | Lessons from Home Experiment Kits for Traditional Introductory Physics Labs

Presenting Author | *Daniel Howard, Oglethorpe University*
Additional Author | Mariel Meier, Oglethorpe University

The use of custom, inexpensive home experiment kits during the pandemic revealed several strategies that will be applied to traditional teaching of introductory physics labs at Oglethorpe University. These include: using the PHYPHOX app and smartphone sensors; cost-effectively increasing the number of onsite lab stations using kit parts so more students are directly involved in running the experiments; having each student collect their own data and write up results with them while still collaborating with team members; limiting the number of formal lab reports required after students demonstrate documentation skills in order to focus on spreadsheet development and conceptual knowledge; and having home kits available even when onsite so students can use them remotely for custom projects based on standard experiments. In particular, having all students collect and analyze their own data virtually eliminates the 'freeloader' syndrome where some students do far less work than others on experiments and documentation.

A1.5-04 | Look Under Your Chair, Because You're All Getting Oscilloscopes!

Presenting Author | *Shawn Reeves, EnergyTeachers.org*

We want to ask students to see patterns in time-series graphs of voltage. Traditionally, we put bulky, expensive oscilloscopes on the benches or made everyone share, or didn't even have one for our classroom. Now, we're teaching circuits with Tinkercad, or we're having students do self-directed projects with Arduinos, both with on-screen graphs of voltage over time. This is helping me teach reading time-series graphs to pre-high-school students; and logical approaches to patterns, and measuring time, to college students. We'll look at videos of oscilliscopes, simulated oscilloscopes, and similar tools.

A1.5-05 | Working Together Alone: Collaborative Inquiry using Cell Phone Apps

Presenting Authors| *Nancy Ruzycki, University of Florida, Herbert Wertheim College of Engineering, Department of Materials Science and Engineering;* Nancy Ruzycki, University of Florida

The EQuIPD grant is a Department of Education Funded teacher professional development program centered on use of core content models, modeling instruction all practices and use of technology for collaborative inquiry experiences for students. As districts pivoted to new learning environments owing to COVID, teachers were placed in either hybrid, FTF or virtual classrooms. The grant has worked to support teachers in new forms of collaborative inquiry in several ways including sending kits home to students, teacher demonstrations/students analyzing data sets, virtual experiments and using cell phone apps (Arduino Science Journal, phyphox and Physics Toolkit. This talk will highlight the support for teachers to implement these new modes of inquiry and showcase some example lessons where students used cell phone apps to collect and analyze data in collaborative teams through an inquiry process to develop a core concept model in physical science. This model is appropriate for students at any level.

A1.5-06 | Keepers: From Remote Studio Physics Back to In-person

Presenting Author | *Andrew Duffy, Boston University, Physics Department*

Our algebra-based introductory physics class for life science students is entirely remote this year. The course is typically taught as a highly interactive multi-section studio class. It was a challenging transition but, by making extensive use of Zoom breakout rooms, we think we have done this fairly successfully. The transition has been a tremendous amount of work. The things we plan to retain when we eventually go back to in-person teaching include: (1) using interactive Google doc worksheets, rather than a printed workbook; (2) spending less time presenting slides and more time with students working together; (3) regular low-stakes quizzes instead of a few high-stakes tests; and (4) streamlining the course, with fewer topics and not as many moving parts. This talk will go over details of these features, which seem to have worked well and which we hope will make for a better student experience in future semesters.

A1.5-07 | The STEMcoding Approach to Distance Learning

Presenting Author **|** *Chris Orban, Ohio State / STEMcoding Project*

The STEMcoding project launched in 2017 with a series of "physics of video games" activities designed for high school physics and physical science. Many of these activities are described on the STEMcoding YouTube channel (http://youtube.com/c/STEMcoding) and we have trained dozens of teachers through various workshops. In 2020 these resources became a lifeline for many of these teachers who needed to find solutions for distance and hybrid learning. And over summer 2020 we redesigned nearly all of our activities with this in mind. This talk provides and overview of how 2020 has shaped the STEMcoding project.

A1.5-09 | Lessons from Virtual Laboratories

***Presenting Author** | Tetyana Antimirova, Ryerson University*

The pandemic timeline has turn out to be much longer than initially predicted, and the need for a remote teaching will be the norm for many more months (if not years) to come. The immediate switch to the remote teaching that happened due to COVID-19, not surprisingly, had the greatest detrimental effect on laboratory components of physics courses and challenged academic integrity during testing. Smaller courses during summer time allowed us to test different approaches and more adequately prepare for large-enrollment classes for the upcoming Fall semester. Decisions when to choose between the labs with real data or simulations-generated data will be discussed. I will touch upon the challenges and successes of running the live lab sessions on teleconferencing platforms such as Zoom. Some elements, like pre-recorded introductions to the labs, methods of lab reports collections and grading online will be useful well past the pandemic.

A1.06 | (A1.06) Upper Division Undergraduate

January 9, 2021 | 12:00 PM - 1:15 PM

Sponsor: *Committee on Contemporary Physics*

A1.6-03 | Evaluating Explicit Incentives to Correct Mistakes in Upper-Division Electromagnetism

Presenting Author | Andrew Mason, University of Central Arkansas
Additional Author | John Colton, Brigham Young University

Brown et al. (1) demonstrated that explicitly incentivizing students in quantum mechanics to correct their mistakes on midterm problems assists students on improving their performance on the same problems as featured on a final exam. We discuss a similar investigation into a first-semester upper-division electromagnetism course, taught at a large research university in the Mountain West, in which 25 students were similarly given explicit incentives to rework three unit exam problems (one for each of three unit exams). For each problem, we compare students who chose to rework their errors for credit with students who did not. We discuss initial findings as follows: for one of the three problems, the explicit incentivization shows a statistically significant benefit for students who accepted the incentive. For the other two problems, certain issues (e.g. an unexpected ceiling effect on midterm attempts) are discussed in terms of affecting outcomes.

(1) B. R. Brown, A. Mason, and C. Singh, "Improving performance in quantum mechanics with explicit incentives to correct mistakes." Phys. Rev. PER 12 (1), 010121 (2016).

A1.6-04 | Remote Undergraduate Research Experiences during Covid-19

***Presenting Author** | Sathya Guruswamy, University of California, Santa Barbara*

Covid-19 has severely restricted undergraduate access to research labs in 2020. Many REU programs and faculty have risen to the challenge by providing remote research projects in lieu of in-person research. Students have shown remarkable resilience in adapting to remote work. In this talk, we discuss the successes and lessons learned from this year's remote research experiences. We explore new horizons this experience has opened in expanding remote research opportunities for undergraduates after Covid-19 restrictions are lifted.

A1.6-05 | 12:00 PM - 01:15 PM | Who Flipped Our Class?

Presenting Author **|** *Andrew Meyertholen, UC San Diego*
Additional Author | *Massimiliano Di Ventra, UC San Diego*

Research-based instructional strategies (RBIS) have been proven effective in improving student learning gains and in reducing course drop rates. Unfortunately, these strategies are not the norm for many physics departments. Studies indicate that some 1/3 of instructors who try RBIS discontinue the use, perhaps because the RBIS were not seen as successful or were viewed as too time consuming. One possible remedy is to have faculty looking to try RBIS co-teach with instructors who've previously used these strategies. We will report on our experiences flipping an upper-level quantum mechanics course working with just such a model. We believe this approach could increase the number of instructors who decide to try RBIS as well as increase the probability that these first attempts will lead to further use.

A1.07 | Quantum Physics in Introductory Courses

January 9, 2021 | 12:00 PM - 1:15 PM

Sponsor: *Committee on Research in Physics Education*

A1.7-01 | Enhancing Learning and Engagement in Quantum Mechanics with Computation

Presenting Author **|** *Jay Wang, University of Massachusetts Dartmouth*

Introductory quantum mechanics can be challenging to students because many concepts are nonintuitive and the development of quantum intuition faces numerous hurdles. One important pathway to developing such intuition through problem-solving is limited due to the fact that few time-independent problems, and virtually no time-dependent problems, are analytically solvable. Computational modeling, however, can be an effective, complementary pathway to developing quantum insight and deepening conceptual understanding. In this presentation we will discuss computation in introductory quantum mechanics with examples to enhance student learning and active engagement (see http://www.faculty.umassd.edu/j.wang/ for some examples).

A1.7-02 | 12:00 PM - 01:15 PM | Muon Half-life and the Inference of Neutrino Decay Products

Presenting Author | *Paul Sedita, QuarkNet*
Additional Author | *Ken Cecire, QuarkNet*
Additional Author | *Shane Wood, QuarkNet*

Muon and neutrino classroom activities and exercises involving experimental data are extremely rare. Using the Arachne viewer for the MINERvA experiment at Fermilab, students can analyze data sets of muon decays to determine the following: the half-life of a muon, the energy spectrum of the daughter Michel electrons, and the existence of two other neutral daughter particles. Furthermore, by cleverly using conservation laws, students can deduce that these neutral particles must be an electron neutrino and a muon antineutrino. In this talk we will present three activities that help achieve student success with this muon decay analysis. First will be a simple rolling of a die activity, followed by the muon decay and lifetime analysis, and finally the deduction of existence of neutrino decay products using conservation laws.

A1.7-03 | 12:00 PM - 01:15 PM | QuarkNet Neutrino Data Workshop

Presenting Author **|** *Shane Wood, QuarkNet*

Large neutrino experiments like MINERvA, NOvA, and MicroBooNE provide data that physics teachers and students can analyze to learn about analysis techniques, practice scientific skills, and learn how physics concepts taught in introductory physics courses apply to contemporary experiments. QuarkNet has created workshops for its member teachers based on activities from the QuarkNet Data Activities Portfolio that build toward an authentic neutrino data analysis from one of the neutrino experiments. In these workshops, teachers discuss and develop implementation plans on how activities, skills, and ideas from the workshop can be transferred into the classroom. We will examine Neutrino Data Workshops, how teachers can get involved, and how the model can be used in teacher professional development.

A1.7-04 | Ghost Particles: Neutrinos for 5th Graders?

Presenting Author **|** *Margaret Norris, Sanford Underground Research Facility / BHSU*

Around the 5th grade, students make a conceptual leap in their understanding of the world around them. In the NGSS, it's at this time that students should be mastering the idea that "matter is made up of particles too small to be seen". How can we help them make this conceptual change? The Sanford Underground Research Facility has developed a curriculum unit to do just that. The unit begins with a phenomenon that all students have seen but maybe not thought about deeply: salt dissolving in water. What happens to the salt? They investigate this phenomenon through the lens of the crosscutting concept 'Scale, Proportion and Quantity'. They develop models to help understand the size of atoms then extend those models to the size of neutrinos. Using these models help students make sense of why scientists need 70,000 tons of argon in future neutrino detectors.

A1.08 | Support for Unprotected Faculty and Teachers

January 9, 2021 | 12:00 PM - 1:15 PM

Sponsor: *Submitting Committee: Committee on Professional Concerns*

A1.8-01 | Supporting Instructors: Building Community and Excellence through Scholarly Teaching

Presenting Author **|** Ellen Yezierski, Miami University

When best practices for teaching are applied to professional development, instructors are supported to challenge their inaccurate ideas about teaching and learning and reconstruct beliefs and teaching practices that have been shown to improve student learning outcomes. The Center for Teaching Excellence (CTE) at Miami University engages learning communities, cohorts, and unstructured groups of personnel who teach in learner-centered programming centered on scholarly teaching. By making programming available to all ranks of faculty, graduate students, and staff, the CTE can support anyone who is interested, including non-tenure track faculty. This presentation will outline the principles, philosophy, and structure of CTE programming, particularly how community building and scholarly teaching are central to its operation.

A1.8-03 | Wright State University Faculty Strike: 20 days in 2019

Presenting Author **|** *Sarah Tebbens, Wright State University*

In January 2019, the Wright State University (WSU) faculty went on strike. This became the second longest strike in US higher education history. In Fall 2018, the administration proposed a contract that included suspending tenure protections, weakening job security for non-tenure track faculty, cancelling a workload agreement (which enabled quality classroom instruction), no raises, and eliminating the right to negotiate health care. The American Association of University Professors (AAUP) WSU faculty voted and, with 94% responding, 85% authorized a strike. After 20 days, a tentative agreement was reached. A new long-term contract was signed that reversed most of the negative terms and included maintaining the workload agreement, providing faculty raises, and maintaining the right to negotiate health care. Faculty concessions included not having salaries restored for the interval of the strike and degraded health insurance. Since the strike there has been a high turnover in administrators, including the President.

A1.8-04 | Leveraging the Community of Students and Faculty to Support Teachers

Presenting Author **|** *Mel Sabella, Chicago State University*
Additional Author | *Andrea Van Duzor, Chicago State University*

Regional institutions that serve local populations are ingrained in the culture and community in which they are located. Local and national views about education and politics surrounding education play a major role in how communities, internal and external, view teaching and learning. This can affect instruction, how resources are used, and how students view the practice of teaching. In 2016, Illinois and Chicago faced severe political and funding issues that threatened and impacted education and services throughout the state, sending strong messages about how education is valued. Despite challenges and ongoing resource needs, institutions are able to leverage the community of students and faculty to enact successful efforts. We provide some historical context around teaching and learning at Chicago State University and describe how community can come together, in the context of the Learning Assistant Model, to establish support for teachers (LAs and faculty), creating the best possible learning spaces.

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

A1.09 | Technology Playground

January 9, 2021 | 12:00 PM - 1:15 PM

Sponsor: *Committee on Educational Technologies*

A1.9-01 | Smartphone-based Virtual Reality for physics with BuckeyeVR

Presenting Author **|** *Chris Orban, Ohio State University*

Most smartphones when placed in a simple $10 plastic viewer become incredibly capable devices for providing virtual reality (VR) experiences. Unfortunately, the learning curve is steep for creating smartphone-based VR content for physics using various software platforms. The Ohio State University led BuckeyeVR group created two free smartphone apps to help teachers create and deliver 3D content using student's smartphones. Importantly these apps produce stereoscopic 3D content so that the visualization provides the viewer with a sense of depth perception. In this talk I will share the BuckeyeVR electric field app which provides VR views of electric field configurations. I will also describe the BuckeyeVR plotter that allows students and teachers to define and view vector fields, curves and surfaces. I will also briefly describe some of the education research we have done using these visualizations at Ohio State.

A1.9-02 | Adding Augmented Reality and Video Games to your Course

Presenting Author **|** *David Rosengrant, University of South Florida St. Petersburg Campus*

In this session, participants will learn how to use various forms of technology to enhance their classroom instruction. The first is Zappar, this is a platform in which you can create your own augmented reality content. You will see some examples in how students have enhanced their instructional materials and you will learn how to do this yourself. Next is an augmented reality simulation utilizing merge cubes that you can download for free. You will learn how to use this simulation in your own classes. Finally, you will learn about how you can create an alternative to the typical back of the book assessment problems. Utilizing video games as a motivational tool you will learn how to not only still practice the content but also to enhance problem solving skills.

A1.9-03 | The Value of Using Simulations to Clarify Simple Concepts

Presenting Author | *Taha Mzoughi*

Most of the physics concepts taught in introductory courses seem very obvious to the teacher. However, the lack of physics "literacy" makes them often very difficult for some students. Simulations can be used to provide simple interactive models toelucidate these concepts. We will demonstrate several examples of how simulations can be used for this purpose.

A1.9-04 | Teaching Experimentation with New Physics in Remote Virtual Reality Labs

Presenting Author | *Jared Canright, University of Washington Department of Physics*
Additional Author | Suzanne White Brahmia, University of Washington Department of Physics

The Novel Observations in Mixed Reality (NOMR) project at the University of Washington applies modern virtual reality technology to teach experimental physics skills by simulating phenomena that do not exist in our universe. By exploring and characterizing unheard-of and Google-proof physical phenomena, students are able to practice experimental physics skills on a level playing field and in absence of a "right answer" to work toward or be judged against. These phenomena are designed with analogy to electrostatics, varying the number of charge types as well as the functional forms and relevant variables in the force laws governing the interactions between each pair of "charges." In this session we discuss the design of NOMR labs, their adaptation to remote usage in a sophomore-level experimental physics course, and initial research findings.

A1.10 | Using Big Data and Machine Learning Understand Physics Outcome

January 9, 2021 | 12:00 PM - 1:15 PM

Sponsor: *Committee on Research in Physics Education*

Co-Sponsor: *Committee on Physics in Undergraduate Education*

A1.10-01 | Addressing Rare Outcomes in PER Quantitative Studies

Presenting Author | *Nicholas Young, Michigan State University*
Additional Author | Marcos Caballero, Michigan State University, University of Oslo

We encounter variables with little variation often in PER due to the demographics of physics and the questions we ask. For example, in course completion studies, most students will earn high enough grades to pass the course. Yet, little work has examined how to analyze such data. Therefore, we conducted a simulation study using logistic regression, penalized regression, and random forest. We systematically varied the fraction of positive outcomes, feature imbalances, and odds ratios. We find the algorithms treat features with the same odds ratios differently based on their imbalance and the outcome imbalance. While none of the algorithms solved the problem, some reduced the scale of the problem. Our results suggest that PER studies may contain false negatives when determining which variables are related to an outcome. We propose recommendations for researchers and then illustrate these by predicting which applicants will be admitted to a graduate physics program.

A1.10-02 | Consistency and Fairness in Introductory Physics Course Grades

Presenting Author | *Andrew Heckler, Ohio State University*
Additional Author | Amber Simmons, Ohio State University

Course grades are concrete outcomes with real-world consequences for students. To what extent are grades, as they are currently awarded, consistent and fair? Higher Educational Institutions are sitting on vast amounts of data that can help us to gain more insight into these questions and perhaps lead us to more desired outcomes. I will discuss three data analytics projects we conducted. First, I will examine how student-level factors such ACT score and demographic group effect grades and exam vs. non-exam grade components. This will reveal demographic disparities. Next, by considering measures of prior preparation, such as ACT scores and prior course grade, I will apply the concept of differential prediction to examine the extent to which grading is consistent between sections, instructors, and semesters, and further examining how consistency between these groups extends to the demographic factors of gender and race. Areas of concern are found for all factors.

A1.10-03 | The Growth of a Quant PER Group (Invited)

Presenting Author **|** *Kenneth Walsh, Oregon State University*

Quant PER is a growing subdiscipline that shows promise in helping our students succeed. My research group has sprouted from this opportunity. I'll talk about building a functioning learning analytics lab, testing waters with exploratory statistics, moving into correlation data mining, and then proceeding onto predictive analytics. We've used machine learning to predict students overall class grade percentage to within about 6% average error, before they even start the class. Come see all the fun things the BoxSand Research Group at Oregon State University is doing.

A1.10-04 | Using Machine Learning to Identify At-Risk Students in Physics Classes

Presenting Author **|** *John Hansen, West Virginia University*

Machine learning algorithms represent an exciting new class of quantitative methods to understand physics classes and students. Recent work has applied these algorithms to understand physics major retention to degree and the risk factors influencing success in introductory physics. This talk will explore the application of these algorithms to identify students most at risk of failure in introductory calculus-based physics. These predictions are complicated by the very unbalanced nature of the samples; most students do not fail physics. Machine learning algorithms will be explored in depth including decision trees and random forests. These will be applied to understand student risk both using institutional variables such as college GPA and within class variables such as homework grades with the goal of making accurate predictions early in the class. Limitations and data requirements for these algorithms as well as their accuracy for underrepresented populations will also be discussed.

A2.1 | PER: Curriculum and Instruction

January 9, 2021 | 1:30 PM - 2:45 PM

A2.1-01 | Responses to Emergency Remote Learning in Introductory Physics

Presenting Author **|** *Matthew Dew, Texas A&M University*
Additional Author | Tatiana Erukhimova, Texas A&M University
Additional Author | Jonathan Perry, The University of Texas at Austin
Additional Author | Lewis Ford, Texas A&M University
Additional Author | Dawson Nodurft, Texas A&M University

Due to the rapidity of the transition to remote learning, instructors had to significantly — if not completely — change their instructional style on very short notice. In this presentation, we report on student experiences and reactions to the switch to emergency remote learning at two large, land-grant, research intensive universities. We aimed to explore how students have received and dealt with the shift to remote learning that began in March 2020, specifically in introductory physics and astronomy courses. To explore how students responded to these changes, we developed and administered a questionnaire gauging the impacts on students' motivation and interactions with their courses, peers, and instructors during the Summer 2020 semester. We also examined how student responses depended on various demographic factors.

A2.1-02 | Teaching Scientific Reasoning through Synchronous Online Physics Labs

Presenting Author **|** *Kathleen Koenig, University of Cincinnati*
Additional Author **|** *Krista Wood, University of Cincinnati*
Additional Author **|** *Lei Bao, The Ohio State University*

The ability to engage in evidence-based decision making is an important outcome of modern education. Over the past decade, we have developed and evaluated a lab curriculum, Inquiry for Student Thinking, Analytics, and Reasoning (iSTAR), which explicitly promotes essential reasoning abilities for scientific inquiry and critical thinking. All activities are grounded in a curricular framework based on operationally defined reasoning sub-skills; including controlling variables in multi-variable contexts, data analytics, and causal reasoning. Due to the pandemic, we have redeveloped the curriculum for synchronous online delivery, whereby student's complete lab activities working in lab groups via Zoom breakout rooms. This talk will briefly showcase the curriculum, lessons learned for online delivery of labs, and impact on student outcomes with a comparison to data previously gathered in face-to-face settings.

**Partially supported by the NSF IUSE 1431908*

A2.1-03 | Evaluating Perceptions of Teaching Changes in Physics for Life Sciences

Presenting Author **|** *Colin Loxley, Western Kentucky University*
Additional Author **|** *Scott Bonham, Western Kentucky University*

Due to the current pandemic many changes were made in instruction of an introductory physics for life sciences. Among these changes were the implementation with an open-source textbook, using a standards-based grading system and using a hybrid class format where students are in class somedays, while working online other days. In order to evaluate student experience and learning student feedback will be obtained by administering open-ended surveys on these changes. The goal of open-ended surveys is to provide a space for students to comment on their behaviors, opinions, and understanding of these changes. The responses to the open-ended surveys will be analyzed to determine what the students think of the changes and follow-up studies will be conducted bases on the responses. This presentation will report on students' experiences to these approaches.

A2.1-04 | Lessons Learned from Classroom Conversations about Ethics, Science, and Society

Presenting Author **|** *Brianne Gutmann, Texas State University*
Additional Author **|** *Egla Ochoa-Madrid,*
Additional Author **|** *Alexander Vasquez, Texas State University*
Additional Author **|** *Daniel Barringer, Texas State University*
Additional Author **|** *Alice Olmstead, Texas State University*

Physics has greatly impacted society, both in solving problems and perpetuating harm. Yet we rarely train students to grapple with their responsibilities to society. The absence of classroom discussions about these impacts reinforces the idea that physics is removed from society. At Texas State University, we have designed and implemented units about ethics, science and society in a modern physics course, an observational astrophysics course, and a multi-disciplinary course focused on this topic. In each of these contexts, we have scaffolded student discussions around large-scale ethical issues related to STEM. In this talk, I will draw on my experiences participating in this work as an instructor and a researcher. I will use video data to highlight factors that enable student engagement, such as curriculum and pedagogy that elicit, push on, and validate student opinions, as well as limiting factors such as students' perceived lack of agency in the physics community.

A2.1-05 | Student Emergent Sense-making about Quantitative Modeling in Introductory Physics Labs

Presenting Author **|** *Charlotte Zimmerman, University of Washington*
Additional Author **|** *Alexis Olsho, University of Washington*
Additional Author **|** *Andrew Boudreaux, Western Washington University*
Additional Author **|** *Peter Shaffer, University of Washington*
Additional Author **|** *Suzanne White Brahmia, University of Washington*

Quantitative modeling is an integral learning outcome of many introductory physics labs. One important aspect of quantitative modeling is covariational reasoning -- reasoning about how one quantity changes with another, related quantity. For example, one might ask 'by how much does the spring force change when the spring is stretched a little bit more?' While covariational reasoning has been studied extensively in mathematics education research, little work has been done in physics education research to better understand and characterize how students' reason covariationally in physics courses. In this presentation, we present features of introductory physics students' emergent covariational reasoning while developing or testing symbolic models in their lab courses. In addition, we compare student and expert physics covariational reasoning to illustrate some potential areas where direct instruction may be improved.

A2.2 | Quantum Information/Quantum Computing in the Classroom
January 9, 2021 | 1:30 PM - 2:45 PM

Sponsor: *Committee on Physics in Undergraduate Education*
Co-Sponsor: *Committee on Laboratories*

A2.2-01 | Quantum Information for STEM Majors and Advanced High School Students

Presenting Author **|** *Theresa Lynn, Harvey Mudd College*

Since 2014 I have taught an introductory quantum information course for general STEM majors, based on notes I am currently developing into a textbook. I report on the structure and content of this course, and its evolution over six offerings so far. Since its inception, this quantum information course has enrolled the majority of its students from outside the physics major (chiefly computer science and mathematics majors). As interest in quantum information science has broadened even over the last six years, I have adjusted materials and presentation to make the course accessible to a wider audience while maintaining the vision of a rigorous and ambitious introductory course. The current course is suitable for the motivated student with a minimal exposure to linear algebra -- matrix multiplication and calculating determinants -- and has been completed by students from all five of the Claremont Colleges as well as several high school students.

A2.2-02 | Quantum Information: An Introduction to Theory & Tools for Teaching

Presenting Author **|** *Frances Tibble, Microsoft*

There's a lot of potential for quantum computers to solve problems in ways that classical computers cannot. At the heart of this potential is quantum information and the way that quantum computers manipulate data. In this session, I'll introduce some basic concepts in quantum computing, such as quantum bits and quantum gates. I'll demonstrate how I make these concepts concrete to the audiences I teach, through the use of small programming-based exercises. By the end of this session, you'll be equipped with the knowledge, learning resources and software tools to help your students explore applications of quantum computing. About the Speaker: Frances Tibble is a Software Engineer at Microsoft Quantum and has a degree in Computing. She enjoys making quantum computing accessible to audiences of varying backgrounds.

A2.2-03 | Teaching Quantum Information Science to Undergraduate Science and Nonscience Students

Presenting Author **|** *Michael Raymer, University of Oregon*

Quantum information science (QIS) has recently exploded as a research and development focus in both academic and industry settings. In the US this growth was accelerated by the National Quantum Initiative, which I was involved in proposing. This talk describes a course on QIS I created at the University of Oregon and that has been adapted to a virtual course for other university's use. The course uses examples quantum optics (photon physics) to introduce QIS, while introducing basic quantum mechanics using essentially no mathematics, but relying on rigorous graphical constructions of the equivalents of QM theory. For the virtual course, laboratory demonstrations were performed live by the company Qutools based in Germany, showing for example violation of the Bell inequality, verifying entanglement of photon pairs created by spontaneous parametric down conversion. The recorded lectures and demonstrations videos will be made available

A2.03 | Undergraduate Physics Education in China
January 9, 2021 | 1:30 PM - 2:45 PM

Sponsor: *Committee on International Physics Education*

A2.3-01 Musical Physics Experiment Teaching @ Home in China

Presenting Author **|** *Junqing Li, Harbin Institute of Technology*
Additional Author | Jinwei Gao, Harbin Institute of Technology
Additional Author | Shan Lin, Harbin Institute of Technology
Additional Author | Weilong Liu, Harbin Institute of Technology
Additional Author | Ancai Wu, Harbin Institute of Technology

During the period of prevention and control of COVID-19 epidemic in China,college students were unable to return to university campuses for study, which affected their physical and mental states. To change the situation, using the network communication tools and combining their home conditions, we carried out online teaching of a series of experiments in musical physics. Using free software like Phyphox students analyzed the musical signals and understood the physical nature of timbre, consonance of combined tones, relation of modes and vibration from Chladni pattern and structural function of a musical instruments they have or self-made. Except knowledge and skills, we also brought happiness to the students. Obviously the teaching effect were excellent. And more importantly, this is a successful attempt to merge Science and Art together through physics and music. We popularized the quality education in Science and Art in fact, which is beneficial to get the promotion.

Partially sponsored by Project of University Physics Teaching Steering Committee of Ministry of Education in China (No DJZW201901db); Planed Project of Education Department of Heilongjiang Province (No GJC1319025), Project of Innovative Experiments of HIT (No CXSY2018011)

A2.3-02 | Exploration on The Heuristic Multi-Leveled Home-Base Physics Experiment Design

***Presenting Author* |** *Jin Wang, Nankai University*
Additional Author | *Wenhua Li, Nankai University*
Additional Author | *Jiang Zhu, Nankai University*
Additional Author | *Wangwei Hui, Nankai University*
Additional Author | *Xiaoqing Wen, Nankai University*

Home-base physics experiment paves an efficient way for the basic physics experimental teaching in this certain epidemic period. Designing of the heuristic multi-leveled home-base physics experiment teaching plan is essential for the guarantee of the student's non-stop study and the teacher's non-stop teaching while the Universities are closed, which also helps to form a teacher-student community in this special period. We should also pay attention to the educational function of the course. Heuristic experiment teaching plan relies on the positive exploration of the teacher, which discards the ritual way on the books. The fast development of International Young Physicists' tournament (IYPT) in China paves the way for deeper reform of the physics experiments courses. The experimental teaching in this special period also gives us efficient indication for the construction of experiment teacher 'team, the construction of library and relative courses.

A2.3-04 |Teaching Reform of Physics Experiment for International Undergraduate Students

***Presenting Author* |** *Jia Jing, Hefei University of Technology*
Additional Author | *Hui Lin, Hefei University of Technology*

The figure of international undergraduate students in Hefei University of Technology has increased significantly to reach a record high in recent years. The physics experiment course education of foreign students is facing new opportunities and challenges. Physics experiments play a distinct role in terms of ability improvement and comprehensive competence cultivation of undergraduate students. It is directly related to the following practical courses. An English version virtual simulation experiment system and Teaching Assistance are applied in the teaching process. Based on the prominent differences in knowledge and the characteristics of physics experiment course, several teaching reform measures has been put forward. From the aspects of teaching link setting, teaching mode exploration, curriculum assessment and evaluation, these measures have improved the teaching quality.

The authors thank the sponsorship of teaching research project of education bureau of Anhui province, China (2018JYXM1001) and the demonstration project of education informationization in Hefei University of Technology (KCXX1904).

A2.3-05 | Teaching Research and Practice of Modern Physics Special Topics

Presenting Author **|** *Hui Lin, School of Electronic Science & Applied Physics, Hefei University of Technology*
Additional Author **|** *Damin Meng, School of Electronic Science & Applied Physics, Hefei University of Technology*
Additional Author **|** *Chengyue Liu, School of Electronic Science & Applied Physics, Hefei University of Technology*
Additional Author **|** *Qiong Tang, School of Electronic Science & Applied Physics, Hefei University of Technology*
Additional Author **|** *Jia Jing, School of Electronic Science & Applied Physics, Hefei University of Technology*

As an extension of University Physics (UP), Modern Physics Special Topics (MPST) is a senior elective course (G3) in our university, a medium level one in China. Special Topic, not Modern Physics, reduces the professionalism and difficulty of contents, and extends its scope. Abundant teaching-materials (e.g. videos, pictures and stories of physicists etc.) and modern teaching-methods (e.g. click-answer, barrage by Rain classroom, and qualitative (non-quantitative) problem-oriented lectures) are used to help undergraduate re-gain confidence in learning Physics. MPST is 32 class-hours and includes some excluded or brief subjects by UP like Einstein's General Theory of Relativity, the theory of energy bands in Solid Physics, Nuclear Physics etc. Different topics are taught by teachers with relevant research backgrounds. In future, we will try to include more topics and develop MPST into a compulsory course. Personalized teaching menu of Physics topics will be carried out according to the backgrounds of different major students.

The authors thank the sponsorship of teaching research project of education bureau of Anhui province, China (2018JYXM1001) and the demonstration project of education informationization in Hefei University of Technology (KCXX1904).

A2.3-06 | Problem Driven Interactive Learning

Presenting Author **|** *Qing Wang, Tsinghua University*

We generalize traditional problem-based learning (PBL) to problem driven interactive learning originated from Socrates. The aim is to teach students how to approach the unknown, by finding, posing, analyzing, and solving problems through student centered interactive learning, in which asking questions actively by students is the key point of teaching process. As a result of interactive learning, both teachers and students are satisfied with the unprecedentedly high level of learning in both their online and face-to-face high-frequency interaction.

A2.3-08 | College Physical Experimental Standardization in China

Presenting Author **|** *Zengming Zhang, University of Science and Technology of China*

The standardization for the general projects in the courses of college physical experiments can help constructing and improving the teaching of college physical experiments in different type of universities and colleges. The standardization for each project consists of scientific background, the multi-level experimental tasks (including basic, enhanced, advanced and challenge), ability training, knowledge tips, connecting subject, and subsequent and extended experiments et al. Each university/college can choose different experiment based on their characteristics and assemble different tasks from same project for students with different subject and class hours each experiment. This work will introduce the progress of the college physical experimental standardization in China.

A2.3-07 | Evaluation the Learning Experience of Lab Courses During the Pandemic

***Presenting Author* |** *Weifeng Su*
Additional Author | *Weijuan Fu, Fudan University*
Additional Author | *Yuan Gao, Fudan University*
Additional Author | *Peixiong Tong, Fudan University*

During the spring semester under Covid-19, following online courses on data evaluation, three modules were offered in the "fundamental physics laboratory" for about 900 freshman students. During their study at home, students were first asked to carry out a project on single pendulum with suitable components, followed by possible improvement and a review session. In the second module, videos on 4 different labs were offered online. Students should watch the video and finish the data evaluation provided as a file. In May, students returned to the campus and finished another four labs in NORMAL teaching laboratory. During the whole semester, students had discussion with teachers and TAs in WeChat groups.A survey was carried out after the course, more than 70% of the students preferred to have labs in laboratory. More detailed results from the survey, as well as hints for teaching lab improvement, will be reported in this talk.

A2.04 | Using and Contributing to the Living Physics Portal
January 9, 2021 | 1:30 PM - 2:45 PM

Sponsor: *Committee on Physics in Undergraduate Education*

A2.4-02 | Initial Implementation of Biomedically-Relevant Introductory Physics Curriculum

***Presenting Author* |** *Mayuri Gilhooly, Rockhurst University*
Additional Author | *Nancy Donaldson, Rockhurst University*

The use of a biomedically relevant active-learning curriculum for pre-health introductory physics has the potential to increase students' engagement with the curriculum by relating physics concepts to their future career interests. My focus in this talk will be on the development of learning activities and assessment questions to support active-learning in an NSF grant-funded biomedically relevant physics curriculum, initial implementation of the mechanics curriculum in a studio-style classroom, and the benefit of this work to my pedagogical growth in teaching physics. I will provide insight into the implementation of this curriculum, informal assessment of students' attitudes toward the curriculum, and how I have adapted it to a hybrid classroom during the pandemic, demonstrating curricular flexibility for student and faculty use both in and out of the classroom.

This work is supported by the grants DUE- 1934038 and DUE-1624007 from the National Science Foundation.

A2.4-03 | 01:30 PM - 02:45 PM | Development of an Active-Learning, Multimedia, Biomedically-Relevant Introductory Physics Curriculum

Presenting Author **|** *Nancy Donaldson, Rockhurst University*
Additional Author **|** *Ralf Widenhorn, Portland State University*

This talk will discuss the first steps of the NSF-funded development of a new type of active-learning introductory physics curriculum – one directed for pre-health students, integrated with multiple, appropriately-placed videos by biomedical professionals and geared toward a study of the relevance of biomedical applications of physics. Curriculum is designed to fill two main needs: 1) provide students with an introductory biomedically related curriculum that stresses the importance of physics as a basic science relevant to medicine, and 2) provide faculty unfamiliar with biomedically related interdisciplinary content with a coherent active-learning physics curriculum that can be implemented in multiple educational environments. To research transferability, implementation is being conducted in introductory physics classrooms at both a small, liberal arts university and a large public university and will be assessed for student content learning and attitudes toward learning physics. All developed curriculum will be contributed to the Living Physics Portal.

This work is supported by the grants DUE- 1934038 and DUE- 1933984 from the National Science Foundation.

A2.4-04 Getting Hot, Messy and Personal with Energy from the Start

Presenting Author **|** *Lane Seeley, Seattle Pacific University*

Traditionally the study of energy in the mechanics portion of introductory physics has focused on clean, idealized scenarios where thermal energy plays a negligible role (balls on ramps, pendula, masses on springs, Atwood's machines, etc…) These scenarios are often far removed from the energy systems which capture student interest in the "real world" or in the life sciences. Once you introduce living beings into the system for energy analysis it is difficult to keep everything idealized and thermal energy becomes an essential player. This presentation will provide audience members with a chance to engage in and discuss an activity which challenges learners to think creatively and rigorously about physiological energy. Students at Seattle Pacific University delve into this challenging activity in the fourth week of introductory physics and tap into a wealth of intuitions and bodily experiences with energy. Supported in part by NSF grants DRL-122273 and DRL-8211.

A2.4-05 | Building Community and Better Pedagogy through the Living Physics Portal

Presenting Author **|** *E. Prasad Venugopal, University of Detroit Mercy*

In recent years, there has been a significant growth in the curricular resource available to instructors teaching Introductory Physics for the Life Sciences (IPLS) courses. The development of the Living Physics Portal site has helped faculty engaged in curricular redesign of our IPLS courses build a shared sense of community, while also providing excellent curricular materials for modification use and in our courses. In this talk, I will share my experiences participating in the Living Physics Portal community. Using examples from scaling laws, mechanics and electrostatics, I will describe how curricular materials from the portal have helped student engagement in my IPLS courses. I have also participated in the portal's "curriculum swap" working groups where faculty from across the U.S. and beyond discussed and shared ideas on course design, pedagogical methods, and instructional challenges in physics courses. This talk will reflect on the opportunities and challenges in these community-building initiatives.

A2.05 | Astrobiology & Exoplanets
January 9, 2021 | 1:30 PM - 2:45 PM

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

A2.5-01 | Los Angeles Pierce College/NASA MUREP Solar System Lab

***Presenting Author* |** *Travis Orloff, Los Angeles Pierce College*

In 2019 Los Angeles Pierce College, with support from NASA's Minority Undergraduate Research and Education Program, developed a new Introduction to the Solar System Lab course to support the already existing, similarly-titled, lecture course. In this lab course students: use video games (PlanetMechanic, Kerbal Space Program, and Universe Sandbox) to explore the universe on their terms; observe 30+ different meteoritehand samples including some from Mars and the Moon;3d print original designs and build lego robots, then combine their knowledge in both topics to develop a miniaturized model of a mission to a destination in space based on a mission design they create from NASA JPL's game Astrobiobound. We discuss the first semester of the course (Fall 2019) but the Spring 2020 semester was canceled part way through due to an inability to fully transition online after COVID.

Project funded by grant from NASA MUREP Innovations in Space Technology Curriculum

A2.5-02 | 01:30 PM - 02:45 PM | A Fermi Paradox Survey

***Presenting Author* |** *Michael LoPresto, University of Michigan*

When pondering the question of whether or not life exists elsewhere in the galaxy, Enrico Fermi asked his now famous question" If they are out there, why aren't they here?"" Towards the end of a large enrollment one – credit, semester - long course on" Aliens," students were asked which of the three general answers:1-We ARE alone; 2-We ARE NOT alone and they are NOT here; or 3-They ARE here,but we don't KNOW it; they subscribed to and why. The responses were then used to create a Fermi Paradox Survey in which students were asked again to choose one of the three general answers then choose from possible reasons fashioned from common student responses in the "Aliens" course. Results from the "Aliens" course and the Survey's use in a more general astronomy course covering the solar system, exoplanets and life will be discussed.

A2.5-03 | Extraterrestrial Life: Science Fact or Fiction?

***Presenting Author* |** *Ann Schmiedekamp, Penn State Univ Abington*

The existence of extraterrestrial life has been in human imagination for a long time, and is portrayed in many fictional media works. Topics in astrobiology have also been popular subjects for scientific documentaries which seek to explain optimism that living organisms could exist on bodies in our solar system or around stars other than our Sun. How well do they communicate real scientific understanding? A interdisciplinary university course was developed to train students in critical thinking as they analyze both scientific veracity and the effectiveness of techniques in designing an educational documentary. Examples of movies portraying missions to Mars or to the outer solar system are also analyzed with respect to accurate representation of current scientific understanding. The objective of this course is to develop skills for students to be critical consumers of film media on the subject of extraterrestrial life.

A2.5-04 | A Cosmic Perspective: Searching for Aliens, Finding Ourselves

Presenting Author **|** *Jill Tarter, SETI Institute (retired)*

Are we alone? Humans have been asking this question throughout history. We want to know whether there is life beyond the Earth and whether any of it is intelligent. Since the middle of the twentieth century we have had tools that permit us to embark on a scientific exploration to try to answer this old question. We have discovered extremophiles in the most unexpected places on this planet and we have discovered that there really are far more planets than stars out there. We haven't yet found life beyond Earth, but there is a vast amount of potentially-habitable real estate to explore. As we look up and look out, we are forced to see ourselves from a cosmic perspective; a perspective that shows us as all the same, all Earthlings. This perspective is fundamental to finding a way to sustain life on Earth for the long future.

A2.5-05 | Exoplanets -- Moving from Discovery to Understanding

Presenting Author **|** *Douglas Caldwell, SETI Institute*

In less than 25 years, the study of exoplanets has grown from a niche field to one with groups at most universities, international conferences, and prominent NASA and European missions. Exoplanet discoveries have moved from individual finds to announcements of hundreds of planets at a time. Currently, there are more than 4,200 confirmed exoplanets with the majority of these discovered by measuring the dimming as they pass in front of their host star. The discovery of thousands of exoplanets by NASA's Kepler Mission has shown that planets orbit most stars in our Galaxy and that potentially habitable planets are common. Scientists are working now to understand the characteristics of these planets, including their sizes, masses, and composition. The TESS Mission has so far found more than 50 nearby planets that can be targets for current and future telescopes to detect and characterize their atmospheres and look for indications of life.

A2.5-06 | Exoplanet Discovery: From the Cosmos to the Classroom

Presenting Author **|** *Ann Marie Cody, SETI Institute*

We are living in an exciting time for astronomical exploration, with an explosion of exoplanet discoveries from ground and space-based telescopes. Many of these discoveries rely on the transit method-- the search for periodic brightness dips as a planet passes in front of its host star. As part of exoplanet transit searches, NASA space missions such as Kepler, K2, and TESS have returned millions of sequential images of the sky. What many people do not know is that these images are publicly available to all, whether astronomer, educator, or curious student. In this presentation, I will discuss opportunities to participate in the search for exoplanets by viewing and analyzing space telescope data. These include the Planet Hunters citizen science project, as well as open source software for those with basic programming knowledge. I will conclude with examples of discoveries made by students and amateur astronomers.

A2.06 | Lecture/Classroom
January 9, 2021 | 1:30 PM - 2:45 PM

A2.6-01 | 01:30 PM - 02:45 PM | Special Relativity using Perplex Numbers

Presenting Author **|** *Shyamkant Anwane, Department of Physics, Shri Shivaji Education Society Amravati's Science College*

Mathematical models involving real-time and imaginary space are efficient in predicting observable effects and beyond. This research paper aims to reformulate the special relativity using perplex numbers or split complex numbers also known as hyperbolic complex numbers which mankind has been familiar with even before we knew about relativity. Hypotheses that time is real and space is imaginary offers a new look at the space-time fabric. The invariant quantities in special relativity are of hyperbolic formats. This eventually leads to hyperbolic geometry that supports the basic structure of equations. The findings support the hypothesis that time is real and space is imaginary in perplex number representation. A few applications of special relativity in the realm of Quantum Mechanics and Nuclear Physics viz Berkley Collider, Compton's Effect, Quantum Doppler Effect have been successfully explored.

A2.6-02 Connecting Experimental Uncertainty to Calculus and to Engineering Design

Presenting Author | Tamar More, University of Portland
Additional Author | *Gregory Hill, University of Portland*

Experimental uncertainty and the epsilon-delta proof provide a rich example of a thread that weaves together topics in introductory physics, calculus, and engineering design. This thread presents an opportunity for deepening the connection between calculus and physics, strengthening conceptual understanding in both fields, and expanding students' understanding of both experimental uncertainty and propagated error as constraints informing the design of an experiment rather than simply an unavoidable consequence of some procedure. We discuss the connections and describe several activities that help students explore the thread.

A2.6-03 | Meta-cognitive Factors of Physics Experiment Learning Difficulties and Teaching Strategies

Presenting Author **|** *JIANSHE LI, School of Electronic Science & Applied Physics, Hefei University of Technology*
Additional Author | *JIA JING, School of Electronic Science & Applied Physics, Hefei University of Technology*

The studies show that the reason of learning difficulties about students is directly related to the lack of metacognitive participation. On the base of the metacognition theory, this paper appeared that the weak task knowledge, the lack of monitoring, the ineffective adjustment and the lack of metacognitive experience are the main metacognitive factors influencing the learning physics experiment. Teachers only know that the lack of what respect metacognitive skills will influence the experimental process study, they will be targeted to improve the metacognitive skills of students with learning disabilities.

The authors thank the sponsorship of teaching research project of education bureau of Anhui province, China (2019jyxm0052).

A2.6-04 | Attitudinal and Motivational Factors in Graduate Students: Cross-sections and Evolution

Presenting Author **|** *Christopher Porter, The Ohio State University*
Additional Author **|** *Andrew Heckler, The Ohio State University*

For the past four years, researchers at OSU have been collecting attitudinal and motivation data from physics graduate students at several universities across the Midwest. The data collected pertain to factors associated with retention at the undergraduate level in STEM, but most of these factors have not previously be studied at the graduate level. These factors include sense of belonging, physics identity, self-efficacy, and cost, among others. In this talk, we will present a brief snapshot of some of these factors for students from different institutions, but at a single time point. We will also look at a longitudinal picture of how these factors tend to change as students' progress toward a Ph. D.

A2.6-05 | Science 100- Educating Students in Science using Energy

Presenting Author **|** *Donald Franklin, Retired/ Consult for Openstax College*

Science 100 is a course designed for students entering college to major in science, but their secondary school did not have all major sciences. This allows the students to work together in groups, no use of curves to cull the students who wanted to become science majors. The students learn about the Energy of Biology, Energy of Chemistry, Energy of Earth and Space Science, and Energy of Physics. This allows the students to determine the future curriculum of their college education. The class is organized as group learning. This allows the students a team of 2 or 3 students. They prepare a Power Point to the class on a topic they choose for each of the four sciences. The Power Point's Speaker Notes would be their Science grade. The Power Point would be graded for their class grades. When the course is completed the students can determine their future curriculum.

A2.07 | Physics and Experimental Research on Black Holes
January 9, 2021 | 1:30 PM - 2:45 PM

Sponsor: *Committee on Space Science and Astronomy*

A2.7-01 | Astrophysics Across the Gravitational Wave Spectrum

Presenting Author **|** *Joey Key, University of Washington Bothell*

We live in the new era of multi-messenger astronomy, with the Laser Interferometer Gravitational wave Observatory (LIGO) and Virgo gravitational wave detectors partnering with telescopes around the world to study cosmic collisions of black holes and neutron stars. This new astronomy allows us to peer deeper into the cosmos and reach farther back into the history of our Universe than ever before. In the coming decades we will explore our Universe using detectors that reach across the gravitational wave spectrum, including a world-wide network of Earth-based detectors, the European Space Agency (ESA) and NASA Laser Interferometer Space Antenna (LISA), and the galactic-scale pulsar timing arrays (PTAs) such as the North American Nanohertz Observatory for Gravitational waves (NANOGrav). We have learned from the history of astronomy to expect the unexpected when opening a new window on the Universe and we now sit on the threshold of a wealth of exciting discoveries.

A2.7-02 | 01:30 PM - 02:45 PM | Adding a Cosmic Soundtrack

Presenting Author **|** *Ben Farr, University of Oregon*

As we approach the fifth anniversary of the first detection of gravitational waves from a binary black hole merger, the LIGO and Virgo detectors have collected an impressive census of compact binary mergers in the local universe. By the end of the second observing run in August 2017 the LIGO Scientific Collaboration and Virgo Collaboration claimed a total of 10 binary black hole mergers and one binary neutron star merger. The third observing run spanned April 2019 through March 2020, during which the collaborations alerted the astronomical community of 56 merger candidates. Thus far, the exceptional events announced by the collaboration include GW190425, GW190412, GW190814, and GW190521. I will present some of what this cosmic soundtrack has taught us about black holes in particular over the last five years, and what may lie ahead.

A2.7-03 | LIGO Status and Plans

Presenting Author **|** *Michael Landry Landry, LIGO Scientific and Virgo Collaborations*

The recent preprint of the second catalog of transient gravitational waves* by the LIGO Scientific and Virgo collaborations reveals 39 events detected in the first half of the third observation run O3. Beginning Apr 1, 2019 and running 11 months, LIGO and Virgo interferometers recorded an average of one likely GW signal every six days, before suspending operations owing to the global pandemic. Novel detections in the first half of O3 include GW190521, a binary black hole merger that produced the first clear detection of an intermediate-mass black hole, and, GW190814, whose constituents include either the heaviest known neutron star or the lightest known black hole. In this talk we review detector performance in O3 and summarize the catalog of transients. We furthermore sketch the pathway to O4 in 2022, including detector upgrades to optics, lasers, and the addition of a frequency-dependent squeezed light source.*https://arxiv.org/abs/2010.14527

A2.7-04 | Unlucky Stars Illuminate Massive Black Holes

Presenting Author **|** *Sjoert Van Velzen, Leiden University*

While most stars will happily orbit about the center of their host galaxy for their entire lifetime, a few of them are less fortunate. These unlucky stars get scattered towards the supermassive black hole at their galaxy center. There they will suffer a tidal disruption and the stellar debris will ultimately disappear into the black hole. These stellar tidal disruptions events are rare and result in a spectacular flare of electromagnetic radiation. Visible from radio to X-ray wavelengths, tidal disruption flares are a unique probe to study massive black holes. Over the last decade, astronomers have gotten increasingly adept at finding these events. The advent of optical transient surveys has accelerated this effort, resulting in a large number of (often unexpected) discoveries. In this talk I will review this progress, demonstrating some the applications of tidal disruption events as tools to study black holes and their host galaxies.

A2.08 | Supporting K-12 Physics Educators
January 9, 2021 | 1:30 PM - 2:45 PM
Sponsor: *Committee on Science Education for the Public*

A2.8-01 | Developing a NGSS Practice Assessment: Planning and Carrying Out Investigations
Presenting Author **|** *Rachel Henderson, Michigan State University*
Additional Author | *Kathleen Koenig, University of Cincinnati*
Additional Author | *Lynnette Michaluk, West Virginia University Center for Excellence in STEM Education*

While efforts have been made in undergraduate science content courses to specifically support pre-service elementary teachers' skills, knowledge, and pedagogical disciplinary knowledge of experimental design, much of this work predates the Next Generation Science Standards (NGSS). To date, few, if any, assessment instruments are well correlated with the NGSS practice Planning and Carrying Out Investigations (PCOI). To meet this need, a team including four faculty members from physics, a social scientist, and a science education faculty member developed an appropriate instrument for measuring students' knowledge of PCOI and, particularly important to pre-service teachers, their students' pedagogical disciplinary knowledge of this practice. The instrument was developed by mapping items to relevant PCOI sub-practices at the elementary grade level, since it was developed for pre-service elementary STEM teachers. In this presentation, we describe the process of developing items in preparation for validation of the instrument.

A2.8-02 | 01:30 PM - 02:45 PM | 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. Fermilab's Lederman Science Center (LSC) houses many interactive exhibits that are available to the public to explore particle physics from a child's point of view. LSC exhibits introduce students to the basic concepts behind Fermilab's science—scale of the universe, symmetry in nature, fundamental particles and forces, accelerators and detectors. These exhibits kick-start and sustain long-term interests that involve sophisticated learning. We believe that learning is broader than schooling, and informal science environments, such as the LSC, play a crucial role in developing the STEM workforce, and stimulating science literacy.

A2.8-03 | Informal and Formal Together: A Science Centre Supporting Schools
Presenting Author **|** *Sandra Eix, Science World British Columbia*

Science World, a Vancouver-based science centre with a provincial mandate, is proud of our long-standing strong and mutually beneficial relationship with K-12 teachers. In the face of changing curriculum in 2015, we comprehensively surveyed teachers province-wide to understand how best to support them. I'll show how we turned the results of that survey into a multi-pronged action plan that included curriculum resources, professional development, and programming for classes near and far. As we rolled out the plan, we created new partnerships with formal and informal science education, and dove into new content (coding and computational thinking!), all of which helped us pivot to successfully support teachers through COVID times.

A2.8-04 | Supporting Pre-Service Primary School Teachers with Hands on Science

Presenting Author | *Irina Marinova, University of Texas - Austin - Austin, TX; Antonia Chimonidou, University of Texas - Austin - Austin, TX*

The science education that pre-service elementary teachers receive shapes their and their students ‘relationship with science. Elementary school teachers report low confidence and low enthusiasm when it comes to learning and teaching science. The Hands on Science (HoS) program at UT Austin was created as part of the successful UTeach program, to serve the unique needs of Applied Learning and Development majors. HoS consists of four required content courses: Physics, Chemistry & Geology, Biology, and Astronomy & Earth Climate. HoS classes were designed using best-practices from education research to meet the specific needs of future elementary school teachers. They differ from traditional introductory science courses in two ways: our students learn the specific content they will later be expected to teach, and they learn it through hands-on inquiry. They attain higher learning gains and show improved attitudes towards learning and teaching science, compared to students in traditional lecture-based intro classes.

A2.8-05 | OnRamps Physics: Experiencing UT-Austin at Texas High Schools

Presenting Author | *Jason Dowd, University of Texas at Austin*
Additional Author | Elyse Zimmer, University of Texas at Austin

OnRamps provides distance education courses via a dual enrollment model—in which UT-Austin faculty, learning specialists, and experts in college success partner with Texas high school (HS) districts to implement courses—to more than 38,000 students across Texas. The goal of OnRamps is to increase the number and diversity of students who are prepared to excel at the university level. OnRamps currently offers two introductory physics courses that have grown from a pilot program of 16 HS instructors and approximately 500 students to a current cohort of over 170 instructors and over 6,000 students across Texas. OnRamps provides yearlong professional learning and development—virtually and in-person—to these HS instructors to implement courses with fidelity, enhance expertise, and boost student engagement. We will explore these and other aspects of the OnRamps Physics instructor and student experiences.

A2.8-06 | Experience with the QuarkNet Big Analysis of Muons in CMS

Presenting Author | *Nicole Preiser, Burr and Burton Academy*

International Masterclasses offered by QuarkNet give students a chance to engage in authentic particle physics data analysis. In the spring of 2020, most of the masterclasses had to be canceled. In order to still provide the opportunity for students to engage in authentic data analysis and interact with physicists, QuarkNet offered the Big Analysis of Muons in CMS (BAMC). Teacher and student experience with this simplified version of the traditional masterclass will be discussed, including experience with lessons that teachers could do remotely with students to prepare them for the data analysis, user-friendly online tools for the data analysis, the talk by a physicist to provide background, and the live discussion of the results. The BAMC allowed students to experience how large collaborations can work together to produce a result and to learn how some of the concepts they were discussing in class are applied in current physics research.

A2.8-07 | 01:30 PM - 02:45 PM | Feasibility of Ecological Interventions to Reduce Teacher Stress

Presenting Author **|** *Julie Carver, Dallas Independent School District*

Studies show that teacher stress is at an all-time high. In recent years, job related stress for teachers escalated due to role intensification, high stakes testing, school shootings, and societal unrest. The pandemic has only added to this stress. “Teacher well-being has been greatly impacted by the covid-19 pandemic (due to) secondary trauma and shifting needs and demands (which leave) teachers on call day and night.” (5) Best practices to combat teacher stress include implementing support structures such as mentoring, team flexibility, and stress management training, in addition to actively promoting teacher health initiatives. However, the most impactful and lasting means of reducing teacher workplace stress would be the adoption of “ecological interventions” designed to shift the public’s perspective on teachers’ role in society. (4) This talk will discuss the overall success of various support structures on reducing teacher stress, as well as debate the feasibility of long term “ecological interventions.”

A2.8-08 | William Crookes (1832-1919): Scientific Communication, Physics, Chemistry and Psychic Phenomena

Presenting Author **|** *William Palmer*

One hundred and one years after his death, the breadth of William Crooke’s scientific work and discoveries still evokes surprise, as many may not be familiar with his achievements.Crookes started his scientific career at the Royal College of Chemistry when just 16, winning a scholarship within a year and becoming an assistant to the Director, August Hofmann. He was interested in photographic research but took a post as assistant at the Radcliffe Observatory in Oxford and then became a teacher in Chester. He married Ellen Humphrey and changed positions several times as editor of various photographic journals. He founded Chemical News which remained his main source of income for the rest of his life. His subsequent career included the discovery of thallium, agricultural research, health research, the invention of the well-known radiometer, work on cathode rays and psychic research. He died on 4th April 1919.

A2.09 | PTRA Presents Perimeter: Evidence for Climate Change
January 9, 2021 | 1:30 PM - 2:45 PM

Sponsor: *Submitting Committee: Committee on Physics in Pre-High School Education / Co-Sponsoring Committee: Committee on Physics in High Schools*

A2.10 | What to Say When your Students Ask About Condensed Matter
January 9, 2021 | 1:30 PM - 2:45 PM

Sponsor: *Committee on Contemporary Physics*

A2.10-01 | Condensed Matter Physics in Introductory Physics: Hiding in Plain Sight

Presenting Author **|** *Danielle McDermott, Pacific University*

Material properties such as pressure, tension, conductivity and elasticity arise due to the complex interactions of atoms and electrons. Interaction forces such as friction also have atomistic origins. Our textbooks may mention these ideas in advanced topic boxes, but what do you say when a student wants to know more? In this talk, I will give a brief overview of the field of condensed matter physics. I will describe how condensed matter physics is present not only in our physics curriculum, but in daily life in technologies such as semiconductors, fiber optics, light-emitting diodes (LED's), and liquid crystals. The talk is intended for anyone who teaches introductory physics, from college physics to secondary science teachers -- both high school and middle school.

A2.10-02 | Condensed Matter Experiments that Use Strongly Interacting Electrons

Presenting Author **|** *Ethan Minot, Oregon State University*

Young students are often enamored by the promise of exotic fundamental discoveries in the field of high-energy particle physics. Unfortunately, it is less often that I meet a young student who sees condensed matter physics in the same light. To help inspire more students to pursue condensed matter, I'll start by illustrating how both fields (condensed matter and high-energy) are at the frontier of fundamental understanding. There is a fruitful exchange of theoretical concepts and theoretical techniques between the two fields. Then, I'll highlight a few condensed matter experimental systems, from my lab, and from colleagues at other universities. The common theme will be exotic phases of matter that arise when strongly interacting electrons dance with each other: in carbon nanotubes, in graphene, and at the interface between semiconductors and superconductors. This talk is intended for anyone who teaches introductory physics, from high school to college.

A2.1-01 PA | Career Paths for PER Students (undergrad to grad and after)
January 9, 2021 | 1:30 PM - 2:45 PM

Sponsor: *Committee on Graduate Education in Physics*
Co-Sponsor: *Committee on Physics in High Schools*

A2.9-01PA | Career Paths for PER students (undergrad to grad and after)

Presenting Author **|** *Alexandru Maries*

This panel session will bring four speakers together who have very different career paths (R1 university, R2 university, teaching college, and high-school) to discuss their chosen careers, in particular, the considerations that led them to where they are today, as well as their own perceptions of their careers at the current moment. The goal of this session is to provide useful information for PER students (both graduate and undergraduate) and answer their questions about potential avenues for employment post-graduation.

A2.11 | Quantum Physics in Introductory
January 9, 2021 | 1:30 PM - 2:45 PM

A2.11-01 | What Heisenberg Knew: A QuarkNet Data-Based Student Activity
Presenting Author **|** *Michael Wadness, Medford High School/QuarkNet*

Many teachers have struggled to connect quantum principles to the traditional high school curriculum. Often these ideas are part of off-topic discussions in which they are simply asserted or partially explained in a hand-waiving manner. This presentation introduces a QuarkNet activity in which high school students analyze simple momentum and position data collected from a 2001 diffraction experiment to empirically discover the famous inverse relationship known as the Heisenberg Uncertainty Principal.

A2.11-02 | Development of Semiclassical Tic-Tac-Toe for Introductory Quantum Mechanics Students
Presenting Author **|** *Joshua Qualls, Morehead State University*
Additional Author | *Keaghan Knight, Morehead State University*

Quantum tic-tac-toe (QTTT) is an educational tool illustrating novel features of quantum systems. Most versions include states, superposition, collapse, and entanglement. While QTTT can provide a foundation for understanding quantum principles, QTTT can also be overwhelming for students new to quantum mechanics. In this talk, we introduce a simplified version of QTTT that does not include entanglement: semiclassical tic-tac-toe (STTT). As a first step toward a systematic development of interactive quantum computing demonstrations and curriculum, we have designed materials for an STTT lesson plan and pilot study. Materials include a pre- and post-test over basic quantum mechanical ideas, an instructor's guide to STTT and QTTT, and a classroom-ready Python-based program featuring classical tic-tac-toe, STTT, and QTTT. We are implementing a pilot study to explore their effectiveness in communicating scientific content and the extent to which the inclusion of STTT might enhance student knowledge in introductory physics courses.

A2.11-03 | The Qubit and Quantum Computing- A Simulation in the Classroom
Presenting Author **|** *Jorge Kuhne*

After presenting therical evolution and basic entities starting with the qubit it goes to a simple practical demonstration using common components (magnets attraction and repulsion) the six qubit states. Completing these ideas finalizes with a quantum teleportation of one

A3-SPS.1 | SPS Undergraduate Oral Talks
January 9, 2021 | 3:00 PM - 4:00 PM
Sponsor: *Society of Physics Students*

A3-SPS.1-04 | Probing Understanding of Buoyant Force and Volume of Fluid Displaced
Presenting Author **|** *Caleb Barber, Grove City College*
Additional Author | *DJ Wagner, Grove City College*

As a part of our larger research on students' conceptions on fluids, our group has been developing a taxonomy categorizing alternate conceptions about buoyancy and giving assessments in various introductory courses to determine the prevalence of selected taxonomy items. Along with this, we are analyzing student understanding of the constructs, or core ideas, that are necessary for understanding buoyancy. In this poster, we describe a few selected assessment questions focusing on the volume of fluid displaced and the relationship between buoyant force and pressure and the constructs they probe, and we compare the most prevalent distractors to their corresponding alternate conception.

A3-SPS.1-01 | Developing a Digital Collaborative Problem Solving Space

Presenting Author **|** *Patricia Shiebler, Hamilton College*

For traditionally in-person teaching environments, COVID-19 creates challenges to student use of academic support structures and organic growth of peer-to-peer learning communities. Simultaneously, collaboration, communication, and problem solving skills are important for success in higher education and beyond. To address this, a digital Collaborative Problem Solving Space (CPSS) and problem presentation assignment were implemented during class time in an introductory physics course. The CPSS gives students the time, space, and peer tutor and instructor support for working together on assignments, while the presentation component asks students to work through more difficult physics problems together. In this talk, I will discuss the implementation of the CPSS, and the results from course observation, student surveys, and student interviews assessing the CPSS in the context of the course learning goals. Perceived strengths and future revisions for better results will also be discussed.

A3-SPS.1-02 | Teaching Inertial Reference Frames Using Simulations

Presenting Author **|** *Daniel Olson*

Despite their introduction in beginning physics courses, many students often struggle with the concept of reference frames when they begin their studies on relativity. To address this issue, I have focused my undergraduate research on creating an educational simulation that can be used as a teaching aide in lessons on inertial reference frames. The simulation uses an adjustable animation of a box falling off the back of a pickup truck from the perspective of two different reference frames. I have also prepared a teacher's manual and student worksheet which can be used with the simulation for a short, hands-on lesson in a classroom environment. In this presentation I will cover the simulation's feature set, how it can be implemented into high school and first year undergraduate physics courses, and how the simulation can be improved to better supplement lessons.

A3-SPS.1-03 | The Effects of Decaying Dark Matter on The Hubble Constant

Presenting Author **|** *John Yevoli, Manhattan College*
Additional Author | *Bart Horn, Manhattan College*

We analyze models of decaying dark matter, searching for shifts in H_0 and σ_8 to resolve the tensions between linear and astrophysical measurements. While previous searches have focused on dark matter with lifetimes on the order of the current Hubble time, we instead consider dark matter that decays between the time of last scattering and the era of large scale structure. We find that while decaying dark matter pushes parameter likelihoods in the right direction to resolve the Hubble Tension, the bounds (Ω = 0 to 10^-2 for lifetimes a tenth of the Hubble Time) on decaying dark matter are too strong to resolve the tension completely, a conclusion unchanged even when spatial curvature is allowed to vary. In addition, these bounds can be used to constrain theoretical models such as coupled axions from string compactifications.

B1.01 | 21st Century Physics in the Classroom II
January 10, 2021 | 1:00 PM - 2:15 PM

B1.1-04 | 01:00 PM - 02:15 PM | Improving Positive Attitude in Learning Physics
Presenting Author **|** *Rahmat Rahmat, SCC*
Additional Author | *Sau Kuen Yam*

Positive attitude is important in learning physics. Students and teachers can have fun together inside and outside classrooms.

B1.1-01 | QuarkNet LHC Data Workshops
Presenting Author **|** *Kenneth Cecire, University of Notre Dame*

QuarkNet has created workshops for its member teachers based on actual particle physics data. One great source of that data is the Large Hadron Collider (LHC) at CERN. In an LHC Data Workshop, teachers build up to an authentic LHC data analysis experience by trying out and reflecting on activities from the QuarkNet Data Activities Portfolio, which themselves often involve LHC data. All of these can be shared with their students. We will examine LHC Data Workshops, how teachers can get involved, and how the model can be used in teacher professional development.

This work is supported by the National Science Foundation and the University of Notre Dame.

B1.1-03 | QuarkNet High School Cosmic Ray Projects
Presenting Author **|** *Mark Adams, QuarkNet at Fermilab*

QuarkNet High School students and teachers have collected data on cosmic ray muons. Their data is available to all on the i2u2.org site and enable measurements of fundamental particle properties. High school and university users can also request groups to modify detector setups in order to collect customized data. Some QuarkNet high school groups have also carried out several more complex projects, e.g. Solar Eclipse 2017, MUSE at Fermilab, and storm tracking, that required assembling an entire particle physics collaboration.

B1.02 | Doing Laboratory Activities in an Online Learning Environment
January 10, 2021 | 1:00 PM - 2:15 PM

Sponsor: *Committee on Physics in High Schools*

B1.2-01 | 01:00 PM - 02:15 PM | Remote Photon Quantum Mechanics Labs

Presenting Author **|** *Enrique Galvez, Colgate University*

The campus shutdowns due to the pandemic posed a serious challenge to labs, especially advanced labs. We offer a lab component to our upper-level quantum mechanics course based on photon labs. We adjusted by setting our labs to be remotely operated. We automated the labs using USB-based rotating or translating mounts, which moved optical components. Arduino-based circuits allowed remote control of the equipment (laser and detectors) and data acquisition. A webcam gave a view of the apparatus. A student connected to other group members by zoom logged into the lab computer via remote PC, and screen-shared the remote-desktop view. The PC controlled the apparatus via serial-port windows. An advantage was that we needed only one setup, and students could pick a convenient time to do the lab. The lab instructor was available online for consultation. It lacked a hands-on component, but exposed students to troubleshooting remotely.

B1.2-02 | Impact on Self-Efficacy, Lessons Learned from Emergency Remote Introductory Labs

Presenting Author **|** *Paul DeStefano, Portland State University*
Additional Author | *Caspar Croft, Portland State University*
Additional Author | *Megan Dubay, Portland State University*
Additional Author | *Ralf Widenhorn, Portland State University*

Prior to March 2020, few introductory undergraduate physics laboratories were offered in the distance-learning format. This work follows a Summer talk describing new lab curriculum and research study for the emergency remote teaching environment of Spring 2020. Using pre/post-instruction surveys and analysis of lab reports/assignments, we assessed the impact of the curriculum on students. Here, we describe students’ attitudes toward the simulation-based and project-based components of the course as compared to in-person labs they experienced, previously. We also show that students experienced a gain in self-efficacy and favored some aspects of the course over others. Additionally, we found students spent more time on the assignments than anticipated. Students reported engaging with design and modelling skills through the do-it-yourself project, though reports sometimes lacked coherent design methodology or uncertainty analysis. Finally, we share our post-mortem analysis of the course features that contributed to these outcomes and future plans for this curriculum.

B1.2-03 | 01:00 PM - 02:15 PM | Student Perceptions and Learning in Online Labs

Presenting Author **|** *Christopher Varney, University of West Florida*
Additional Author | *Samantha Seals, University of West Florida*
Additional Author | *Aaron Wade, University of West Florida*

Due to COVID-19, introductory physics lab courses were shifted to an online format. The online implementation of the labs involved a shift in emphasis in learning goals and involved a range of activities, including PhET simulations, video data collection, analysis of data sets, and open-ended free response conceptual questions. We contrast student perceptions of the online labs and learning outcomes for asynchronous and synchronous implementations.

B1.2-04 | Online Labs: Learning Scientific Reasoning Skills

Presenting Author | *Krista Wood, University of Cincinnati*
Additional Author | Kathleen Koenig, University of Cincinnati
Additional Author | Lei Bao, The Ohio State University

Following AAPT Lab Guidelines, we developed the Inquiry for Scientific Thinking, Analytics, and Reasoning (iSTAR) Lab curriculum that explicitly promotes the development of reasoning skills needed to design controlled experiments, collect and interpret empirical evidence, and make claims based on that evidence. iSTAR Labs are highly structured, inquiry-based labs. Each lab activity has explicit Student Learning Outcomes (SLOs) with assessments to measure the SLOs. For Fall 2020, we converted iSTAR Labs to Synchronous Online Labs using standards from Quality Matters (QM), the leading quality assurance organization in online learning. This talk will address how we incorporated best practices of effective online course design including: (a) explicitly addressing learner interactions; (b) providing learner support for course technology; and (c) creating accessible course materials. We will also discuss the implementation of iSTAR Online Labs, lessons learned, and impact on student outcomes at a two-year college.

B1.2-05 | Collaboratively Developing Experimental Physics Skills in Hybrid Virtual Reality Labs

Presenting Author | *Jared Canright, University of Washington Department of Physics*
Additional Author | Suzanne White Brahmia, University of Washington Department of Physics

Virtual reality (VR) physics labs that employ fictitious physical phenomena to provide students an opportunity for authentic physics model development are under development at the University of Washington. In these labs' remote incarnation, one member of each group of 6-7 students attended in person to operate VR hardware. The in-person student collaborated with their group via video call. This hybrid format lent itself well to VR labs. An in-VR student communicates with their partners only by voice whether instruction is virtual or not; thus the remote adaptation of this approach made minimal functional difference in collaborative group dynamics. Our findings suggest that VR technology can enable robust student collaboration in remote experimental physics lab contexts. In this talk I will compare and contrast the student in-person VR lab experience to its virtual counterpart, and identify implications for the design of remote physics laboratory curriculum.

B1.03 | Effective Practices in Educational Technology II
January 10, 2021 | 1:00 PM - 2:15 PM

B1.3-01 | Physics Alive: Sharing Education Insights and Research through a Podcast

Presenting Author | *Brad Moser, Hamilton College*

We physics teachers seek the latest education research findings, new curricular ideas, and inspiration to buoy our spirits and imagination. But we live busy lives; it is hard to find time for reading and researching new ideas. Meanwhile, podcasts are a rapidly growing form of media; not just for entertainment, but for learning about the world. What if there were a podcast dedicated to physics education? Now there is! Physics Alive is a podcast where I speak with teachers who employ innovative and active learning styles, researchers and textbook authors on the frontiers of physics education, life science and health professionals who use physics on an everyday basis, and students who want the most out of their education. In this talk I share major themes of the podcast and how I hope to disseminate excellent research. I also seek your input for making it better! Visit physicsalive.com

B1.3-02 | Keys to Keeping Students Engaged

Presenting Author | *Jennifer Palomino, Texas State University at San Marcos*
Additional Author | *Kristin Wedding Crowell, California State University, East Bay*
Additional Author | *Travis Orloff, Los Angeles Pierce College*

We review key lessons learned when taking our small group active learning classes online, both in synchronous and asynchronous modes. We considered engagement with the material, the instructor and with other students. Five key techniques emerged as being most important: Clarity, technology, opportunity, feedback, and flexibility. Since communication of course structure and expectations are always important, and because each campus relies on different Learning Management Systems, our talk will focus on different ways to provide engagement and ideas for both providing and receiving feedback. Once feedback is flowing, flexibility will allow you to adjust or review whatever is needed to keep your students on track and engaged. This is part of a series of talks stemming from the NextGen PET FOLC project. This work was supported by the National Science Foundation grant NSF DUE-1626496.

B1.3-03 | The New Smart Cart Motor from PASCO scientific

Presenting Author | *Daniel Burns, PASCO scientific*

The new Smart Cart Motor from PASCO scientific opens a wide variety of possibilities for the study of motion. It can be used to generate many novel motion profiles by responding to inputs from the attached Smart Cart. It can respond to inputs from any PASCO sensor using PASCO Capstone or SPARKvue's software's built-in Blockly programming. This unleashes student creativity to control motion based on temperature, light, sound, magnetic field, and the actions of another Smart Cart. Computational thinking in the classroom has never been so engaging and exciting. Several applications will be demonstrated during this talk and sample code and lab activities will be distributed. The Smart Cart Motor will become your new favorite PASCO scientific product!

B1.3-04 | Community Building with SPS - Virtually

Presenting Author | *Mikayla Cleaver, American Institute of Physics, Society of Physics Students*

Building strong undergraduate communities effectively is important to student success. Due to the COVID-19 pandemic and current social distancing guidelines, colleges and universities have had to adapt many of their normal activities, such as classes and club gatherings, to virtual platforms. This may have students feeling more disconnected than normal, which has led the Society of Physics Students (SPS) to strategize building a sense of community within its members more now than ever. With increased social media presence, utilizing the SPS Discord channel, organizing virtual talks, and more, SPS has worked to interact with our students and members to promote community engagement virtually. Learn about the SPS virtual initiatives and how you can get involved or implement them in your own community.

B1.3-05 | Visuohaptic Simulations Enhancing Learning in An Applied Physics Course

Presenting Author **|** *Hector Will, Purdue University*
Additional Author | Alejandra Magana, Purdue University
Additional Author | Lynn Bryan, Purdue University

A challenge that engineering students usually face when moving forward from an introductory physics course into a statics course concerns the resolution of trusses. The challenges include applying basic concepts on statics, such as identifying forces and drawing free-body diagrams on the trusses joints. This study explores students' use of a visuohaptic truss simulation in a statics lab using three different modalities: visual, visuohaptic, and sequenced haptic+visuohaptic. While the visual simulation allowed students to observe the force's magnitudes and directions, the visuohaptic simulation also allowed students to feel the forces acting in the members of a truss. Findings suggest that by providing visual and haptic feedback, students get to experience rich embodied experiences, fostering the development of richer mental representations of the topic, and transfer it to truss resolution. Learning through the haptic device fosters conceptual understanding and the correct use of force direction while solving exercises with trusses.

B1.3-06 | A Case Study of Learning Geometrical Optics Using Multiple Representations

Presenting Author **|** *Markku Jääskeläinen, Mälardalen University*
Additional Author | Roger Andersson, Mälardalen University
Additional Author | Gunnar Jonsson, Mälardalen University

A group of secondary students, learning geometrical optics using a computer simulation, was followed. The aim was to observe the students learning progression with a focus on their ability to draw correct rays in the formation of an optical image. The teaching was based on activities focused on testing hypotheses, supplemented by computer simulations. Each session started with the students individually predicting the answer of the task by drawing a ray diagram and explaining their reasoning in words. As the students were followed longitudinally, they increasingly exhibited signs of having developed a physically correct understanding. Their increased understanding of the formation of image points was exhibited in the students´ discussions. The student's construction of rays improved from them being able to handle single rays, towards mastering multiple ray construction. The student's discussions, transcribed from video recordings, show that the students focused on solving the tasks using multiple rays.

B1.3-07 | Energy Flow in Spring Coupled Pendula: Measurements and Analysis

Presenting Author **|** *Michael McCusker, Foothill College*
Additional Author | Jeffery Anderson, Foothill College

We discuss new experimental and analytical studies of the familiar pair of spring-coupled-pendulua (SCP). This system is frequently used to introduce eigenvalue analysis and coupled differential equations (1). We extend the tutorial value of the SCP by measuring and modeling energy "flow." Specifically, we follow the time behavior of the system energy as it flows between kinetic energy, gravitational potential energy, and spring potential energy. We follow three different states: symmetric motion, the first normal mode, antisymmetric motion, the second normal mode, and mixed-mode motion modeled as a linear combination of the two normal modes. We compare our modeled behavior with experimental measurements we make using a simple, effective, and low-cost system (2). We use these studies to supplement an Applied Linear Algebra Course that involves hands-on measurement of dynamical systems and explorations that go beyond what is found in most textbooks.

1) Jeffrey A. Anderson & Michael V. McCusker (2019) Make the Eigenvalue Problem Resonate With Our Students, PRIMUS, 29:6, 625-644, DOI: 10.1080/10511970.2018.1484400 2) Project

Support Website
https://www.youtube.com/playlist?list=PLSt7rwoPGTy2Jtf13gXh2MvSeo24xSgGv (This site has a general introduction to this project as well as additional tutorial materials.):

B1.3-08 | Assessment Options for Remote Learning: Alternatives to Traditional Exams

Presenting Author **|** *David Mitchell, Cal Poly, San Luis Obispo*
Presenting Author | *Tamar More, University of Portland*
Presenting Author | *Deepshikha Shukla, Rockford University*

We present several ideas for alternative assessments in courses taught virtually. We will discuss video and photo assignment alternatives to exams, such as mini-lessons, photo blogs, and community-based learning, that allow students to engage with, and demonstrate their mastery of, course concepts. This is part of a series of talks stemming from the NextGen PET FOLC project.

This work was supported by the National Science Foundation grant NSF DUE-1626496.

B1.3-09 | Interactive Online Lectures with Clicker Questions

Presenting Author **|** *Robert Teese, Rochester Institute of Technology*
Additional Author | *Michelle Chabot, Rochester Institute of Technology*
Additional Author | *Kathleen Koenig, University of Cincinnati*
Additional Author | *Alexandru Maries, University of Cincinnati*

In online or flipped courses, instructors often assign asynchronous online lecture videos. However, in-classroom and synchronous lectures frequently include interactive elements such as clicker questions. The goal of this project is to create a set of Interactive Online Lectures that foster active learning in an asynchronous format. Six lecturers at four diverse institutions are creating and sharing the lecture videos and interactive elements for the first semester of an introductory calculus-based course. Each lecture consists of several short (5 to 8 minute) video lecture segments interspersed with required multiple-choice "clicker questions" designed to help students understand the lecture content. After submitting each answer, the student sees an explanation of why the answer is correct or incorrect. The lectures are currently being used at five institutions either as primary or supplementary materials. Sample lectures and instructions for signing up to use the lectures at no cost can be found at https://ivet.rit.edu/IOL.

B1.04 | Get the Facts Out!
January 10, 2021, 1:00 PM - 2:15 PM
Sponsor: *Committee on Physics in High Schools*

B1.4-01 | An Asynchronous, Interactive, Get-The-Facts-Out Activity and More
Presenting Author **|** *Joshua Grossman, St. Mary's College of Maryland*
Additional Author | Angela Johnson C, St. Mary's College of Maryland

We have created a web-based, asynchronous, interactive, Get-the-Facts-Out activity for providing students with information about the benefits of a career teaching physics. The format enables us to provide the activity to multiple groups with minimal effort after initial implementation. Students in the gateway, third-semester physics course and several upper-level physics courses were assigned the activity as part of the physics major/minor career curriculum, as were students in educational studies courses. We will share preliminary data on the state of knowledge as students began the activity and on their self-reported learning and changes in attitude afterward. Earlier, not long after the US onset of the pandemic, we conducted a live, online, Get-the-Facts-Out presentation to faculty in all of the STEM departments and Educational Studies at St. Mary's College of Maryland.

This work is supported by a PhysTEC Recruiting grant.

B1.4-02 | 01:00 PM - 02:15 PM | Recruiting Physics Teachers in a Virtual World
Presenting Author **|** *Wendy Adams, Colorado School of Mines*
Additional Author | Savannah Logan, Colorado School of Mines
Additional Author | Jared Breakall, Colorado School of Mines

The Get the Facts Out Project is an ambitious effort to change the conversation around physics, chemistry, and math teacher recruitment. We are utilizing best practices from cognitive science, communications science, education research, and multimedia learning to create effective ways to persuade faculty to view the teaching profession with a new lens and to leave the door open to this great career option. Did you know that teachers in the United States rate their lives better than all other occupation groups, trailing only physicians? In this presentation we will share updates on our latest resources and research results including effective strategies for recruitment in a virtual world.

This project is supported by NSF DUE-1821710.

B1.4-03 | User Testing of Teacher Recruitment Videos, Images, and Other Materials

Presenting Author **|** *Savannah Logan, Colorado School of Mines*
Additional Author | Jared Breakall, Colorado School of Mines
Additional Author | Wendy Adams, Colorado School of Mines

We have developed and extensively tested written and visual teacher recruitment materials as part of the Get the Facts Out (GFO) project in an effort to correct the nation's science and math teacher shortage. First, we worked with experts to develop taglines, sentences, and other written materials based on our research on perceptions of the teaching profession. Additionally, we identified appealing photos and videos related to teaching. Next, we tested and refined these materials over two years using faculty and student focus groups at several US universities. Recently, we began collecting large-scale data via a national online survey. Our results provide insights into optimal recruitment strategies, and we will share some of our unique findings based on location, demographics, and target audience.

This project is supported by NSF DUE-1821710.

B1.4-04 | Teacher Recruitment: Focus Group Insights from Six Universities

Presenting Author **|** *Jared Breakall, Colorado School of Mines*
Additional Author | Savannah Logan, Colorado School of Mines
Additional Author | Wendy Adams, Colorado School of Mines

Teachers in the United States rate their lives better than all other occupation groups, trailing only physicians. Despite this fact, there is a shortage of secondary math and science teachers in this country. One reason for this disparity is a lack of accurate and positive information about the profession. To correct this disparity, the Get the Facts Out (GFO) project has developed research-based, user-tested materials that provide accurate messaging about teacher happiness, autonomy, and financial well-being. As part of this project which investigates how these resources can affect the number of math and science majors who pursue grade 7-12 teaching, we have collected in-person and virtual focus group data from students and faculty members at 6 universities from around the country. These results provide insight into perceptions of grade 7-12 teaching and into how GFO resources are being used in recruitment efforts. Implications for teacher recruitment will be discussed.

B1.4-05 | Getting the Facts Out about Physics Teaching at Lewis University

Presenting Author **|** *Joseph Kozminski, Lewis University*
Additional Author | Dorene Huvaere, Lewis University
Additional Author | James Hofmann, Lewis University

Lewis University is in the first year of its PhysTEC Recruiting Grant, which is intended to help increase the number of physics teacher candidates. Lewis has a B.A. in Physics for High School Teaching Licensure and an M.A. in Secondary Education, and we have historically graduated one physics teacher per year on average. As part of this grant work, we are developing a new accelerated Bachelors in Physics to Masters in Secondary Education track. We are also modifying Get the Facts Out materials to reflect data from the Chicagoland region and are using these materials to educate faculty about high school physics teaching as a career, to recruit current majors at the University into physics teaching, and to recruit high school and community college students. This presentation will discuss these efforts, including how we have modified our recruiting plans to engage these groups remotely due to the pandemic.

B1.4-06 | It's All About Perspective: Where an Aeronautical-university fits into GFO

Presenting Author **|** *Richard Pearson III, Embry-Riddle Aeronautical University*
Additional Author | *Wendy Adams K, Colorado School of Mines*

This talk addresses the collection methods, plans, and preliminary baseline data for Embry-Riddle Aeronautical University--a private, aeronautical-focused university that may be considered quite removed from the secondary teacher pipeline. The underlying presumption of the "Get the Facts Out" (GFO) project is that perceptions of grade 7-12 teaching impact the number of undergraduates who choose to enter that profession. Changing the conversation around the grade 7-12 teaching profession at institutions with deliberate and focused efforts to recruit, train, and prepare secondary physics teachers is, of course, of upmost importance. However, the GFO project aims to reach anyone who influences employment decisions of undergraduate students. Therefore, analysis of this and other similar institutions may help serve as a measure of general perceptions for GFO's longitudinal study.

B1.05 | PER: Diverse Investigations
January 10, 2021 | 1:00 PM - 2:15 PM

B1.5-01 | Exploring the CLASS with Item Response Theory

Presenting Author **|** *John Stewart, West Virginia University*
Additional Author | *Elaine Christman, West Virginia University*
Additional Author | *Paul Miller C, West Virginia University*

This work applied exploratory factor analysis (EFA) and graded Item Response Theory (IRT) to a large sample (N=4522) of Colorado Learning Attitudes about Science Survey (CLASS) post-test scores. EFA failed to reproduce the factor structure suggested by the authors of the CLASS and strongly supported the alternate 3-factor model suggested by Douglas et al. Graded IRT allowed an examination of the progression from non-expert-like to expert-like beliefs. This progression was generally uniform with a linear relation between the difficulty of each step in the progression. Some items within the factors identified by Douglas et al. had difficulty and discrimination parameters substantially different than other items in the factor suggesting the subscale is not unidimensional. The expert-like latent ability trait estimated by IRT correlated more strongly with measures of physics performance than measures of general academic performance indicating that expert-like beliefs are not a general property of high performing students.

B1.5-02 Developing A Model of Key Components of Informal Physics Programming

Presenting Author **|** *Bryan Stanley, Michigan State University*
Additional Author **|** *Dena Izadi, Michigan State University*
Additional Author **|** *Kathleen Hinko, Michigan State University*

Informal physics learning environments bring physicists, physics students, and public audiences together in a variety of formats. Popular events include youth camps, public lectures, and demo shows. However, these format-focused labels do not illuminate underlying factors important for the design and implementation of informal physics activities. Here, we present results from a qualitative research study to investigate the aspects of informal physics programs that are critical to their functionality. Drawing from organizational theory, we code interviews with program leaders for emergent themes within the broad categories of personnel, audience, resources, institution, and programs. The emergent themes form the basis for our developing model of key components that are necessary for informal physics programs to function. We share our current model for these key components and discuss future work to develop practitioner tools to assess programs.

B1.5-03 | Investigating Research Themes for The Physics Education Research Community

Presenting Author **|** *Rebecca Rosenblatt, AAAS-STPF*

A preliminary analysis of research themes investigated by the PER community over the last ten years will be presented. A text-based analysis of all contributed Physics Education Research Conference (PERC) proceedings between 2010 to 2019 is analyzed to look for both emerging and thematic patterns to strategic categories such as areas of research, populations being studied, research questions/goals, and research methods. PERC proceedings were selected given the central role of PERC to the PER community. PERC proceedings represent the community across scope of projects from small to large, across stage of projects from beginning to finished, and across investigator experience from new to established researchers. The goal of this work is to provide insight into the community's history and trajectory as well as collect a databased of who is working in which strategic area to improve networking and collaboration among Physics Education Researchers.

B1.5-04 | 01:00 PM - 02:15 PM | Students' Attitudes and Beliefs about Physics in Uruguay

Presenting Author **|** *Martin Monteiro, Universidad ORT Uruguay*
Additional Author **|** *Alvaro Suarez, Instituto de Profesores Artigas, Consejo de Formación en Educación, ANEP, Uruguay*
Additional Author **|** *Daniel Baccino, Instituto de Profesores Artigas, Consejo de Formación en Educación, ANEP, Uruguay*
Additional Author **|** *Arturo Marti C, Instituto de Física, Facultad de Ciencias, UdelaR, Uruguay*

Many investigations in the field of Physics Education Research show that students' epistemological beliefs about science and their views on the nature of knowledge and learning, affect their metacognitive practices and academic success. To evaluate these attitudes and beliefs, specially focused on physics, some assessments have been developed. One of those tools is the well-known Colorado Learning Attitudes Survey about Science (CLASS), that have been applied for several studies in many countries, mainly in Europe and North America. However, little is known about students and teachers in South America. In this talk we'll report some characteristics, measured by the CLASS, of the views about the nature of physics and learning physics of physics teachers and students in Uruguay, both in secondary and tertiary education.

B1.5-05 | Short-Term Mindfulness Intervention Improves the Efficiency of Solving Physics Problem

Presenting Author **|** *Cade Hensley, Missouri Southern State University*
Additional Author | *Rabindra Bajracharya, Missouri Southern State University*

The affective domain of learning is one of the emerging fields in physics education research. Mindfulness is an important, but often overlooked aspect of the affective domain. The effects of mindfulness on one's mind-body have been studied in multiple disciplines including psychology and medicine. Many K-12 schools have already started to implement mindfulness practices in their curricula to foster teaching and learning practices. However, there has not been any research on this domain in physics education. We are studying the effects of short-term mindfulness sessions on students' learning processes in physics. The participants in our study completed several five-minute-long mindfulness sessions, during which they observed their breathing objectively. The participants were assigned introductory physics problems before and after the interventions. We found that they solved the problems faster after the interventions. Our results indicate that short-term mindfulness practice may improve physics problem-solving efficiency.

B1.06 | Physics on the Road and Art of Demonstrations (Waxing or Waning?)

January 10, 2021, 1:00 PM - 2:15 PM

Sponsor: *Committee on Science Education for the Public*

B1.6-01 | The Virtual Physics Demo Show: A Primer

Presenting Author **|** *David Maiullo, Rutgers University*

While these rather odd times in society continue, we still strive to bring the excitement of physics to many diverse audiences through physics demonstration shows. I will review the issues these efforts expose, some of the ways we can incorporate fun and informative demonstrations, and the problems one may encounter planning and performing these shows.

B1.6-02 | Teaching to The Child Attending Infant School, Following Walk Trail

Presenting Author **|** *Amalia Maria Kontokosta, Aristotle University of Thessaloniki*
Additional Author | *George Kontokostas E, National and Kapodistrian University of Athens*

Walking trailis geographically localised around kindergarten. Different phenomena are used as trigger for education. The designed walk trail is a practical endorsement, where the students will use fieldwork skills, to identify physical phenomena through the built environment. They view physical phenomena with a holistic approach, improving their ecological consciousness. We attempted to follow research steps, set forth by inquiry-based learning: a) trigger for interest, b) reminder of basic knowledge/formulation of hypotheses, c) experimentation/trials, d) formulation of conclusions, e) applications/generalization according to learning.

B1.6-03 | 01:00 PM - 02:15 PM | Mobile Physics Outreach during a Global Pandemic

Presenting Author | Bruce Bayly, University of Arizona
Presenting Author | Christopher DiScenza A, University of Florida
Presenting Author | Erik Herman A, Cornell University
Presenting Author | John Perkins F, The Physics Factory

The COVID-19 pandemic has upended how every educational organization operates. Outreach programs are hit especially hard, considering the potential for child-to-child virus transmission via hands-on equipment and community spread through traveling from one location to another. The Physics Factory (www.physicsbus.org)has been examining a variety of operational changes so that we can continue inspiring children with the excitement of science without endangering their health or their families. These changes will be implemented in our newly-acquired 8th Physics Bus, which will be serving Gainesville FL and surrounding communities. During our session we will welcome participants aboard and let you explore freely from the safety of your own home.

B1.6-06 | 01:00 PM - 02:15 PM | How to Make Plenty Use of Mirage Demonstration

Presenting Author | *Yuan Zheng, Zhe Jiang University*

As an intriguing optical phenomenon in nature, mirage is widely known and often demonstrated in physics classes when introducing optic basics. Although some typical photos and videos can be easily found in the internet, they are often disorderly mixed and somehow confusing. How to conduct a quick and interactive mirage demonstration with appropriate lecturing is full of challenge. In this discussion, a simplified way to create inferior mirages with ethanol and water in a small container are presented, which is very suitable for classroom presentation. Various multi-image mirages are demonstrated by a simple apparatus, which are elaborately designed for lecturing continuous reflection and refraction in the medium with concentration gradient.

B1.6-07 | Bringing Physics Lecture Demonstrations Closer to Home

Presenting Author | *Katrina Henry, Virginia Wesleyan University*
Presenting Author | Zachary Hubbard D, Virginia Wesleyan University

Lecture demonstrations are frequently noted on teaching evaluations as being an engaging part of lecture. However, the Force Concept Inventory (FCI) post-test indicates student retention of demonstration concepts is poor. Furthermore, lecture demonstrations require a significant amount of instructor preparation and time in lecture. Because of these issues, and limited class time in Fall 2020 due to COVID, an introductory physics class moved a portion of lecture demonstrations to independent student activities completed outside of class. It was hoped that students independently performing the demonstrations would increase retention of concepts. The instructor and TA's made a "Physics Box" of supplies for lecture demonstrations, paid for by lab fees. Students report enjoying doing the demonstrations themselves and using the equipment in the Physics Box creatively while working quantitative problems. Nonetheless, they also reported uncertainty in their results and a desire to discuss them in class.

B1.6-04 | Physics Class and Lab on the Softball Field

Presenting Author **|** *Matthew Wright, Wright*
Additional Author | *James St. John P, Adelphi University*

We will discuss our unique approach to teaching physics in the age of COVID. We set up alternate tracks for our calculus-based physics course that allowed for active learning, introduction to scientific computing, and provided flexibility for students to attend in person classes or online classes when appropriate. The two tracks were outside physics in person literally on the university softball field and asynchronous online. We will share details of the approach as well as lessons learned.

B1.07 | Student Topical Discussion & Social
January 10, 2021 | 1:00 PM - 2:15 PM

Sponsor: *Committee on Research in Physics Education*

B1.7-01PA | Student Topical Discussion and Social

Presenting Author **|** *Danny Doucette, International School of Latvia*

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

B1.08 | Teaching Science in a Culture of Mistrust
January 10, 2021 | 1:00 PM - 2:15 PM

Sponsor: *Committee on Physics in Two-Year Colleges*

B1-8.01 | A Thermodynamic approach to Climate Science

Presenting Author **|** *Frank Lock, Georgia State University Woodrow Wilson Foundation*

This presentation will provide an overview of presentations that will be available to those attending for use with their classes. The presentations are intended for use with students in grades 6-9, 10-12, and introductory college classes. Climate science challenges are presented in terms of entropy changes that occur due to procuring and burning fossil fuels to produce electricity. Information about the Climate Reality Project is also included.

B1.8-02 | Are Religion and Science Dichotomous? Evidence from Faith and Observation

Presenting Author **|** *Najib Azhar, Averroes High School*
Additional Author | *Abdullah Siddique, Averroes High School*
Additional Author | *Levi Leveridge, Averroes High School*

Adorno and Horkheimer’s The Dialectic of Enlightenment (1944/1947) considers the historical development and dialectical entwinement of science and myth: myth is proto-science, while science is a latter-day myth. Each of these seek to comprehend and control/dominate the forces of nature via ritual and experiment Science and Religion both find it expedient to isolate themselves from challenges and critique of the other. The reality of evidence has proven that understanding of science evolves, as does the comprehension of traditional religion. Religious thought tends to remove itself from the reality of observation; construing observed phenomena as magical and inexplicable acts of a Supreme Being. While science is subject to limitations of observation, measurement of phenomena and inconsistencies in environmental conditions and contributing factors envisioned. Evidence shall be presented from both Faith and Observation, exploring hypotheses of synergy and/or discord or a hybrid, projecting the path forward as our understanding of both evolves.

B1.8-03 | An Interdisciplinary Seminar on Knowledge, Science, and Policy

Presenting Author | *Marta Dark, Spelman College*

What is science? What are the psychological, economic, and political factors that shape people's decisions about truth or fact? Do truth, facts, or opinions guide science and technology policies? These are the questions we address in a one credit seminar for first-year students. The seminars were developed as part of Spelman College's Big Questions Colloquia, and they cover many different areas. In this seminar, students learn about how people reason and what science is. Eventually, students build skills to help them critique policies and differentiate between science and pseudoscience. We explore controversial topics like big tobacco, and look at some conspiracy theories, such as the Apollo hoax. From the seminar, students gain experience critiquing, evaluating, and thinking about science and related policies. I will present my experiences with developing the seminar, and some strategies for building an interdisciplinary approach to communicating about science.

B1.8-04 | 01:00 PM - 02:15 PM | Studying the Past to Understand the Present

Presenting Author | *Scott Bonham, Western Kentucky University*

Galileo's trial in 1633 was not the cultural myth of rational science versus irrational religion but rather a notable flashpoint in possibly the most significant cultural paradigm shift in western history. Galileo, colleagues and opponents clashed over metaphysics, epistemology, theology, tradition and even experimental science against a backdrop of armed conflict, religious battles, globalization, nationalism, economic change, information revolution and a reoccurring pandemic—not so different from today. In many respects the geocentric versus heliocentric battle was the premiere socio-scientific conflict which helped shape the emergence of modern science, making it a valuable and (no longer controversial!) case study to help better understand contemporary ones. This talk will describe a new course in which we first study Galileo to understand the nature of science and the many facets of socio-scientific conflicts— history, social identity, foundational assumptions, cognitive biases, conflict theory, rhetoric and argumentation—then apply that understanding to contemporary ones.

B1.8-05 | 01:00 PM - 02:15 PM | The Physics of Healthy Air

Presenting Author | *Aurelian Balan, Delta College*

The air we breathe is constantly changing. The dynamic nature of outdoor and indoor air makes it interesting to measure. There are many natural opportunities in an intro electromagnetism course for students and professors to observe how quantities like carbon dioxide, methane, and particulate matter change over time. We will look at a few sensors that measure various gases and particles in the air. Then we will discuss ideas for integrating them into the intro physics classroom. Understanding what influences the air gives students an interest in the atmosphere around them and offers them a chance to change it with their actions.

B2.01 | Astronomy Education Research I
January 10, 2021 | 2:30 PM - 3:45 PM

Sponsor: *Committee on Space Science and Astronomy*
Co-Sponsor: *Committee on Research in Physics Education*

B2.1-01 | Explorations of Ephemerides by First Year Physics and Astronomy Students

Presenting Author **|** *Duncan Carlsmith, University of Wisconsin - Madison*

This talk will illustrate how to access several of state-of-the-art ephemerides describing the motions of the Sun, all planets and moons, and many asteroids based on fits to essentially all extant data. MATLAB scripts are illustrated which permit detailed studies such as of the impact of any planet on Earth's motion. We address the question: Does the Earth orbit the Sun or the solar system barycenter?

B2.1-02 | 02:30 PM - 03:45 PM | Measuring the Speed of the Earth around the Sun

Presenting Author **|** *Thaddeus Herman, John Jay High School, Hopewell*

A simple radio telescope, built by high school teachers through an NSF-funded summer program, was used over the course of a year to measure the speed of the Earth around the Sun. The telescope is designed to measure the spectral signature of neutral hydrogen, which is pervasive in the Milky Way Galaxy. By pointing the telescope at the center of the galaxy, meant as a fixed reference point outside the Solar System, the doppler-shifted spectra taken over the course of a year was used to the measure the Earth's speed. The construction of the radio telescope, and the physics behind the experiment is well within the grasp of high school and college physics courses. The website with the radio telescope build instructions and associated curricula with be discussed in the presentation.

B2.1-03 | Timing Pulsars: Exercise in Statistical Analysis and the Scientific Process

Presenting Author **|** *John Walkup, California State University, Fresno*
Additional Author | *Roger Key, California State University, Fresno*
Additional Author | *Avery Sheldon, California State University, Fresno*

A lab activity for teaching statistical analysis and the scientific process is described. This activity involves students timing sound clips of pulsars. To select the most precise timing methods and to calibrate their measurements to account for bias, students first time pulsars of known periods. Students then turn their attention to timing an unknown pulsar. Using an online database, students search for pulsars of periods within a statistically-determined range. This activity arises from the need for students to leverage the power of statistics to (1) optimize lab procedures through data-driven decision-making, (2) correct for bias through calibration, and (3) gauge the quality of their work in terms of confidence rather than correctness. This three-step process aligns lab procedures closer to industry practices and elevates cognition/engagement. This lab activity is also easily disseminated online, making it ideal for those institutions unable to meet face-to-face during the pandemic.

B2.1-04 | Mentoring Undergraduates Teams in Variable Star Research

Presenting Author **|** *Matthew Perkins Coppola, Purdue University Fort Wayne*

An open call on our campus to physics majors yielded seven students with varied backgrounds in astronomy and no experience with research. This qualitative case study provided insights into the challenges and successes of each group as they participated in the thirteen-week short course on RV Tauri variables created by Michael Fitzgerald. Student teams met weekly to collaborate with one another, the local mentor (author), and Dr. Fitzgerald. Observations in B, V, i, and z wavebands were collected via remote telescope network over a two-week period and analyzed using Python. Student teams determined the period of variability and estimated the distance using empirically-derived period-luminosity relationships. Throughout the process students wrestled with the nature of science and scientific inquiry, generating several questions. Students initially struggled to appreciate the significance of the results, likely a consequence of myopic focus on calculation. Implications for mentoring teams in astronomy research are presented.

B2.1-05 | Testing Formal Reasoning Skills: An Updated Approach

Presenting Author **|** *Shannon Willoughby, Montana State University*
Additional Author **|** *Steven Kalinowski, Montana State University*

Tests of scientific reasoning have been around since the 1970’s, including the well-known two-tiered Classroom Test of Scientific Reasoning (CTSR) by Lawson. However, some of the questions asked on CTSR are specific to benchtop science experiments, and modern psychometric tools had not been invented to thoroughly test the test. Starting from a large pool of test items, the 20 item MSU Formal Reasoning Test (FORT) was iteratively developed. This one tier test covers the following concepts: control of variables, hypothesis testing, correlational reasoning, proportional reasoning, and probability. The final version of the FORT was given to 240 students, and item response theory (IRT) analysis was performed on each question, using a 3-P model. In this talk, I will discuss several questions on the FORT and their associated IRT curves. Additionally, I will share results of the FORT for samples of physics and astronomy students.

B2.1-06 | Introduction of Computational Activities to a General Education Astronomy Course

Presenting Author **|** *Raymond Zich, Illinois State University*
Additional Author **|** *Andrew Princer, Illinois State University*
Additional Author **|** *James DiCaro, Illinois State University*

This study investigated the effects of introducing computational activities to a general education astronomy course taught using active learning techniques. Computation is an important active learning tool for developing understanding of concepts, connecting concepts with formulae, and associating science with prediction. Spreadsheet based computational exercises were tied to lecture-tutorials, think-pair-share activities, and group worksheets. These exercises were completed in a collaborative environment. The results of this curriculum modification are discussed, along with reflections on the factors leading to the introduction of computational activities, factors that supported the change, and barriers faced while implementing this change. These findings are compared with results from other case studies of instructional change and theories of adoption. Student learning pre to post was measured with the TOAST and LPCI, and qualitative data was collected in the form of student surveys to investigate student learning, attitudes toward computational exercises, and overall perceptions of the course.

B2.1-07 | Students' Sense of Belonging in Introductory Astronomy Labs

***Presenting Author* |** *Caitlin Kepple, San Francisco State University*
Additional Author **|** *Bahar Amin, San Francisco State University*
Additional Author **|** *Kim Coble, San Francisco State University*

Students' sense of belonging in science has been identified as a predictor for students' motivation, self-efficacy, and persistence in the field—especially for historically underrepresented students. In this research, we explore the various contributors and potential barriers to students' sense of belonging as it applies to an introductory general education astronomy labs. We collected a number of attitudinal surveys from lab students spanning between Spring 2018 to Spring 2020. Through the use of iterative thematic coding, we have developed a set of themes based on student-reported contributors and barriers to their sense of belonging in a scientific environment. This study is being conducted at San Francisco State University; a Hispanic-serving institution and one of the most diverse large universities in the country. Through this research, we hope to give further voice to a population of students that may not yet be well represented in the current literature.

B2.1-08 | Tools to Improve Writing, Thinking, and Reasoning in Astronomy Courses

***Presenting Author* |** *Sanlyn Buxner, University of Arizona*
Additional Author **|** *Matthew Wenger, University of Arizona*
Additional Author **|** *Alexander Danehy, University of Arizona*
Additional Author **|** *Chris Impey, University of Arizona*
Additional Author **|** *Martin Formanek, University of Arizona*
Additional Author **|** *Maria Galloway-Sprietsma, University of Arizona*
Additional Author **|** *Maria Galloway-Sprietsma, University of Arizona*

Introductory astronomy courses are popular as undergraduate electives and as free choice learning experiences, currently delivered as Massive Open Online Courses. Research has shown that utilizing writing assignment in science courses are important to make learner thinking visible and help improve science reasoning. We will present a suite of tools and strategies, iteratively revised through our research, that are being used to improve engagement and writing in several astronomy MOOCs. We also will present new online tools being developed to identify fake science online. These tools utilize machine learning and are trained by to distinguish reliable and fake ideas in online articles specially about controversial topics such as climate change and evolution. Additionally, another tool is being developed to give computer generated feedback on student writing to improve scientific reasoning and support iterative instructor feedback in introductory astronomy courses. All tools will be available broadly to instructors and online.

B2.1-09 | The Origins build-a-MEL: A Scaffold to Explore the Universe's Origins

Presenting Author **|** *Timothy Klavon, Temple University*
Additional Author | Janelle Bailey M, Temple University
Additional Author | Archana Dobaria S, Temple University
Additional Author | Doug Lombardi, University of Maryland

The origin of the Universe is something that people have pondered for thousands of years. As evidence has mounted, the Big Bang theory has become the consensus scientific model. Much of this same evidence refutes opposing theories such as the earlier Steady State model or the often-held conception of an exploding ball of matter. High school students often have difficulty distinguishing between these competing explanatory models. Also, the NGSS for high school includes the nature of and evidence for the Big Bang, providing students with a rich opportunity to explore, with the help of a scaffold, the connections between evidence and competing models about the origins of the Universe. This presentation will include the development of the Origins of the Universe build-a-MEL scaffold and data from ongoing analyses.

B2.1-10 | Cloudy Night? Astronomy Labs Using Physics Demonstrations and a Videogame

Presenting Author **|** *Nicole Gugliucci, Saint Anselm College*

Even before the current pandemic, astronomy labs at Saint Anselm College had to plan for the many cloudy nights that would prevent a trip to the observatory. In the fall semester of 2019, the indoor lab component centered around the educational video game, "At Play in the Cosmos," which lets students simulate performing astronomical measurements from their spaceship. This was incorporated into the labs using spectral tubes and simulations to introduce new concepts before they came up in the game. With the shift to online learning in 2020, the video game became the centerpiece of the labs once again, providing the students with guidance that is not available in an asynchronous teaching environment. In this session, I'll share some of the techniques used to assess student learning with the video game in the lab and online.

B2.02 | (B2.02) Built-In Assessments
January 10, 2021 | 2:30 PM - 3:45 PM

Sponsor: *Committee on Physics in Two-Year Colleges*

B2.2-01 | General Physics Lab Activities Analyzing Space Weather Observations

Presenting Author **|** *Hugh Gallagher, SUNY Oneonta*

The field of space weather examines the impact of the conveyance of energy and momentum from the sun to near earth plasmas. Many historical and contemporary, ground and space-based observations are easily accessible to the general public. In this presentation, I will describe lab activities that use general physics principles to interpret observations in two such data sets. Data from the LASCO instrument on the SOHO spacecraft is used to examine the kinematic properties of coronal mass ejections and estimate their travel time to Earth's orbit. At the terminus of the solar terrestrial interaction, the IMAGE Magnetometer Network makes observations of the magnetic field at the surface of the Earth. The observed spatial variation in the magnetic field may be used to infer the characteristics of a horizontal current flowing in the upper-atmosphere.

B2.2-02 | Plotting Open Source Data in the Advanced Physics Lab Course

***Presenting Author* |** *Chuck Stone, Colorado School of Mines*
Additional Author | Lawrence Wiencke, Colorado School of Mines
Additional Author | Connor Pierce, Colorado School of Mines
Additional Author | Scott Hunter, Colorado School of Mines

Colorado School of Mines engineering physics majors take a two-semester sequence of Advanced Physics Labs during their junior year of studies that introduce them to laboratory measurement techniques in atomic physics, modern physics, nuclear physics, optics, and solid-state physics. These courses introduce students to measurement and uncertainty, data reduction and error analysis, and effective scientific writing. We require students to use the Python programming language to generate plots that can be imported into lab reports and presentations. To provide an authentic learning experience, students complete a "Python Programming and Plotting Assignment" in the first-semester course before their first set of measurements. In this presentation, we will share open source data students have plotted from COVID-19 Cases Reported at Mines, Lifetime Measurements of the Tau Lepton, Fitting the Cosmic Microwave Background Radiation Spectrum, and student-selected data sets. Faculty, students, and teaching assistants from the courses will share their perspectives.

B2.2-03 | Student Self-grading of Homework in Classical Mechanics

***Presenting Author* |** *Cindy Schwarz, Vassar College*

For Classical Mechanics at the sophomore level, I completely changed the way that homework was graded, using a self-grading/professor review process, 2 years in a row. Students would attempt all problems, then be given access to my complete solution for the assignment. They would grade themselves, most importantly including comments on self-reflection of their work, mistakes, understanding and correcting their errors with full commentary. Getting the correct answer was not the requisite for an excellent score. This was incredibly successful both from the student experiences (confidence and pressure relief), my experiences (insight into student understanding and process, gaps in skills/knowledge) and higher overall grades in the course. I will discuss methods used, examples of student self-graded work, student feedback and the impact on other courses in the department and college.

B2.2-04 | Standards Based Grading for College Physics Courses

***Presenting Author* |** *William Newton, Texas A&M University-Commerce*
Additional Author | Robynne Lock, Texas A&M University-Commerce
Presenting Author | Tamar More, University of Portland

Standards-based grading uses a set of learning objectives rather than individual assignments or problems to determine grades. Standards based grading is common in the secondary education setting, but less so at the college level. We will discuss some of the significant advantages of the approach, especially for online classes, some of the particular challenges for implementing it in college classes, and describe two ways in which we have been able to meet those challenges. This is part of a series of talks stemming from the NextGen PET FOLC project. This work was supported by the National Science Foundation grant NSF DUE-1626496

B2.2-05 | Scientific Explanations: Narrative structure, Prompts and Rubrics

Presenting Author **|** *Lawrence Escalada, University of Northern Iowa*
Presenting Author | Tamar More, University of Portland
Additional Author | Alison Beharka A, University of Northern Iowa
Additional Author | Andrew Boudreaux, Western Washington University
Additional Author | Will Newton, Texas A&M University - Commerce

We discuss student narratives, well-structured scientific explanations, as both formative and summative assessment tools. We will review the elements and organization of the narrative in the context of the NextGen PET curriculum; present some rubrics and metrics for evaluating narratives; suggest scaffolds and assignments to build students' narrative writing (and reading) skills; and share our data and thoughts for the narrative as a particularly useful tool in the context of online classes. This is part of a series of talks stemming from the NextGen PET FOLC project. This work was supported by the National Science Foundation grant NSF DUE-1626496.

B2.2-06 | Group Projects: An Alternate Assessment for Remote Teaching (and Beyond)

Presenting Author **|** *Paul Emigh, Oregon State University*
Additional Author | Alfred DeAngelis, Oregon State University
Additional Author | Brenden Vischer, Oregon State University

The COVID-19 Pandemic resulted in a rapid switch to remote teaching for most university courses. One major concern of many introductory physics instructors has been the security of assessments (such as exams) in this remote environment. As an alternative to the high-stakes exams that are more traditional for introductory physics courses, we assigned group projects to students as an alternative assessment (along with individual low-stakes quizzes). We discuss advantages and disadvantages of putting group projects into practice, such as students' engagement with the project and their affective response to working in groups on a high-stakes assignment.

B2.03 | Champions and Change: Curriculum, Community and Campuses I
January 10, 2021 | 2:30 PM - 3:45 PM

Sponsor: *Committee on Research in Physics Education*

B2.3-03 | Results from Undergraduates Attending a Virtual Summer Meeting

Presenting Author **|** *Amanda Eng, Vassar College*
Additional Author | Cindy Schwarz, Vassar College
Additional Author | Sarah Ziegler, Vassar College
Additional Author | Jesse Nyagah, Vassar College
Additional Author | Sean Garib, Vassar College

This presentation will highlight the outcomes of undergraduate students from Vassar College attending the AAPT virtual summer meeting. Seven undergraduate students attended this online conference hosted on underline.io as part of a for-credit course to be completed during the Fall 2020 semester. The impact of COVID-19 forced students and educators to adjust to virtual learning, making it necessary to share and implement new techniques to continue teaching and engaging students effectively. Fortunately, a shared online platform facilitated the international exchange of ideas from physics educators, graduate students, and undergraduates. Some of these ideas and methods were then shared within the course participants, and will be applied to enhance the Physics Department's approach to various pedagogical issues with online teaching and diversity, equity, and inclusion. Examples of suggestions for physics faculty and students will be shown.

B2.3-04 | QuSTEAM: A New Curriculum Development Project in Quantum Information Science

Presenting Author **|** *Christopher Porter, The Ohio State University*
Additional Author **|** *Andrew Heckler F, The Ohio State University*

The alarming 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) is a revolutionary undergraduate curriculum that will provide a national educational model for the emerging field of quantum information sciences (QIS). The development of QuSTEAM will rely on research-based educational best 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 very early stages. We will describe early emerging themes and models for innovative curriculum and programs integrated with industry.

B2.3-05 | 02:30 PM - 03:45 PM | Driving Undergraduate Departmental Change: Diversity, Equity, and Inclusion

Presenting Author **|** *Brad Conrad, Society of Physics Students / American Institute of* Physics

Undergraduate student leaders and faculty must partner to build thriving physics and astronomy programs. To achieve this aspirational goal and address systemic underrepresentation of African Americans and other groups within our departments, departments need to implement processes for self-evaluation and change. Department culture, SPS, and the role of advising are instrumental in effecting lasting change. This session will aim to examine areas where undergraduate student leaders and faculty can implement the recommendations of the AIP Task Force to Elevate the representation of African Americans in Undergraduate Physics (TEAM-UP) report. The session will focus on self-assessment tools and methods of evaluation for students, faculty, and undergraduate groups.

B2.3-06 | Towards a Framework for Equity-Minded Engineering Integration in Physics

Presenting Author **|** *Shannon Morey, Knowles Teacher Initiative*
Additional Author **|** *Emily Berman R., Knowles Teacher Initiative*
Additional Author **|** *Katey Shirey, Knowles Teacher Initiative*

Many physics teachers are seeking ways to make our courses more just and equitable, including creating units that address issues of social justice and utilize culturally relevant pedagogy. We often feel constrained by the innumerable topics that are supposed to fit into our courses, so how do we weave social justice into our courses and not make it an add-on that feels like one more thing we need to “cover”? Knowles Engineering, a project of the Knowles Teacher Initiative, is focused on helping teachers integrate engineering into their courses using content they already teach. Now, we have developed a framework to help teachers create curriculum that connects to local and global issues of social justice and uses the engineering design process to incorporate culturally relevant strategies. In this presentation, we will provide our draft framework, discuss the development of the framework, and how it can be employed by teachers.

B2.3-07 | International Physics Teacher Leadership: US, Latin America, and the Caribbean

Presenting Author **|** *Rebecca Vieyra, Organization of American States*
Presenting Author **|** *Kensha Foster, Charles E. Mills Secondary School, Saint Kitts and Nevis*
Presenting Author **|** *Jason Douglas, The Anglican High School, Grenada*
Presenting Author **|** *Lynn Jorgensen, Gilbert High School, AZ*
Presenting Author **|** *Carmen del Pilar Suárez Rodríguez, Organization of American States / University de San Luís Potosí, Mexico*

This presentation will feature the stories of multiple physics teachers across the USA, Latin America, and the Caribbean who have participated in the Inter-American Teacher Education Network. Each of these teachers has been recognized for their role as teacher leaders, and they will share how they have worked to impact the policies and practices of their schools and educational systems. These teachers will provide exemplars for how other physics teachers across the hemisphere can become agents of change in diverse ways.

B2.3-08 | Retaining Underrepresented Students through Outreach Programs: A Systematic Literature Review

Presenting Author **|** *Madison Swirtz, Colorado School of Mines*
Additional Author | *Simone Hyater-Adams, American Physical Society*
Additional Author | *Claudia Fracchiolla, American Physical Society*

There is a good deal of focus on recruiting underrepresented students to study physics at the collegiate level, but a lack of focus on how to make sure they are being recruited into a welcoming and safe environment that values their identity. Because of this, underrepresented students tend to feel a disconnect from the physics community and are more likely to drop out or switch majors. One potential method of combating this issue is increasing the peer networks of these students through informal outreach programs, which give students a sense of purpose, belonging, and confidence in physics. This systematic literature review synthesizes studies on the effects of informal STEM programs on the facilitators and identifies gaps in this research as it pertains to underrepresented students.

B2.3-09 | Summary of Physics Unlimited's Virtual 2020 Summer Program

Presenting Author **|** *Pavel Shibayev, Physics Unlimited*

As part of our nonprofit's efforts to engage students in the US and around the world in learning physics through innovative practices and to supplement their classroom instruction (or lack thereof, as is the case in 40% of US high schools that do not offer physics classes), we have organized a virtual summer program this past August, consisting of two parts: a summer school and a summer camp. The former constituted a three-week series of nine innovative lessons in general physics, hosted by three volunteer instructors - students from Harvard and UC Berkeley - live via Zoom and recorded for students from different time zones. The latter involved a series of over twenty facilitator-led online networking sessions for participants from nine countries, in addition to career panels. Our free pilot program was well-received, and we plan to organize new iterations specifically targeting underrepresented groups, including prisons.

B2.04 | High School
January 10, 2021, 2:30 PM - 3:45 PM

B2.4-01 | CMS-related activities in LHC Data Workshop
Presenting Author **|** *Jeremy Wegner, Winamac Community High School*

This talk will introduce two High School level contemporary Physics activities that can be easily integrated into a standard High School Physics curriculum in either an in-person or online environment. These are activities that take the concepts of the conservation of mass, energy, and momentum into the relativistic realm and demonstrate the statistical techniques used in HEP analysis. Where to find these QuarkNet activities and others like them on the Data Portfolio section of the QuarkNet website will also be discussed. These are also two activities that can be used as preparation for the LHC Data Workshop to be discussed in later talks.

B2.4-02 | Designing Online Assessments: Inspirations from the 2020 AP Physics Exam
Presenting Author **|** *Kathleen Harper, Department of Engineering Education, The Ohio State University*

The COVID-19 pandemic has caused educators to revisit almost every aspect of teaching and learning, including assessment. In spring of 2020, the Advanced Placement program found itself with the challenge of quickly designing, administering, and grading their exams in a purely online environment. This talk will share observations of the 2020 AP Physics exams and discuss how these observations helped shape the author's design and administration of online exams and quizzes. Examples of several styles of questions administered through the course management system at the author’s university will be included.

B2.4-03 | 02:30 PM - 03:45 PM | Can Newton's Second Law be Modified?
Presenting Author **|** *Amritpal Nafria,*

Additional Author | Darshan Singh,
In this paper, a more general expression (F=ma+r) to Newton’s second law of motion (F=ma) for calculating the net force acting on the bodies including various external forces (r) due to air resistance, friction, etc. has been proposed by proving it practically. This net force acting on a body is the combination of two forces i) An applied force on a body till body remains stationary (r) and ii) other part of the applied force, when the force exceeds and body starts moving and produces acceleration (ma). As per our study, today’s scientific community or text books are calculating the net force acting on a body without considering the external forces means simply by applying ‘F=ma’ but in actual practice, where the applied force goes till the body remains stationary and the effect of external forces? Therefore, we have taken care of these factors to calculate the net applied force.

B2.4-06 | Identifying “Tempered Radicals” in the STEP UP Ambassador Program

Presenting Author **|** *Ben Archibeque, Florida International University*
Additional Author **|** *Joineé Taylor, Florida International University (FIU)*
Anne Kornahren **|** *American Physical Society*
Additional Author **|** *Pooneh Sabouri, Florida International University*
Additional Author **|** *Zahra Hazari, Florida International University (FIU)*

For the past fifty years, undergraduate physics programs have struggled with the underrepresentation of women. The STEP UP project (STEPUPphysics.org) was designed to reduce barriers for women in physics and encourage high school women to pursue an undergraduate physics degree. STEP UP focuses on implementing high school interventions by working with cohorts of high school physics teachers called Ambassadors, who are trained to teach and propagate STEP UP's research-driven materials throughout their teacher networks. To understand the effects of Ambassador training, several surveys are being administered to Ambassadors throughout the school year. Taking a “tempered radicals” framing, this talk will present an analysis of initial survey responses and the characteristics of teachers who are willing to be disruptive in order to reduce barriers. Results will inform the future selection of Ambassadors, guide STEP UP training, and be relevant to other programs seeking to develop “tempered radicals” in their communities.

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

B2.4-05 | Jupyter Notebooks in the High School Classroom

Presenting Author **|** *Paul Beeken, Byram Hills High School*

Jupyter notebooks [JN] are rapidly becoming the tool of choice of rmodelling the mechanics of physics calculation and investigation. This open source tool is used in research, engineering as well as computer and data science. It can also be an effective tool for classroom use at the high school level as well. A framework for introducing and using jupyter notebooks as a model for student engagement in topics presented at the high school level will be presented. In the form of Google's CoLab (a cloud-based implementation of JN) it can also allow remote interaction with distance learning students through shared documents as well.

B2.05 | PER: Diversity, Equity & Inclusion
January 10, 2021 | 2:30 PM - 3:45 PM

B2.5-01 | URM Grouping Hides Struggles of Black and Asian American Students

Presenting Author **|** *Devyn Shafer, University of Illinois at Urbana-Champaign*
Additional Author **|** *Maggie Mahmood S., University of Illinois at Urbana-Champaign*
Additional Author **|** *Tim Stelzer, University of Illinois at Urbana-Champaign*

We conducted a series of multiple linear regressions to examine the predictive ability of race on introductory mechanics final exam scores when controlling for ACT math scores and physics placement test scores. When we followed a common method of categorizing students as URMs and non-URMS for our analysis, we found that students who earned comparable scores on the ACT math test and the physics placement test performed similarly on the final exam. However, when we established separate groups for Non-Hispanic White American, Asian American, African American, Hispanic, International, Multi-Race, AIAN, and NHPI students, we found that African American and Asian American students, and to a lesser extent, Hispanic students, under-performed in their physics course relative to their prior test scores. We conclude that there is still work to be done at the university level to provide a learning environment supportive of students of all backgrounds.

B2.5-02 | Practices that Maintain Excellence and Diversity in the COVID-19 Era

***Presenting Author* |** *Christopher Porter, The Ohio State University*
Additional Author | Geoff Potvin, Florida International University
Additional Author | Galen Pickett, California State University Long Beach

The COVID-19 outbreak has introduced unexpected barriers and uncertainty for prospective graduate students and physics departments. Chief among concerns are the safety and health of students, and the economic shortfall resulting from reduced enrollment. Such concerns may significantly disrupt the application and admittance processes; of particular concern is the impacts on the diversity of incoming graduate cohorts. Using exploratory survey data collected from physics departments in Fall 2020, we will report on how COVID-19 has impacted the processes, pressures, and demographics of physics graduate programs, including the effects of various departmental responses and preparation. We will present practices implemented by departments, with special attention paid to those that have been successful in maintaining the size, diversity, and preparedness of the 2020 graduate cohort. The findings of this study will inform on actions related to recruiting, admissions, and/or post-admissions that will support graduate admissions in the coming years.

B2.5-03 | Variations in Practicing Physicists' Beliefs about Inclusive Teaching Strategies

***Presenting Author* |** *Daniel Oleynik, University of Central Florida*
Additional Author | Erin Scanlon,
Additional Author | Jacquelyn Chini, University of Central Florida

There is currently a push by researchers and disability advocates to introduce inclusive teaching strategies and universal design principles into physics classrooms. With this push, it is important to study how the attitudes and actions of instructors vary as they consider implementing these guidelines. We used a modified version of the Inclusive Teaching Strategies Inventory (ITSI) to survey 249 physicists recruited at American Physical Society conferences and through physics-specific listservs. This study presents how practicing physicists' responses varied across different identity markers, such as gender, race/ethnicity, and personal disability experience. We will compare our findings from the physics community to findings from general populations of both students and faculty.

B2.5-04 | Secondary Physics Teachers' Ideas About Integrating Equity into Energy Instruction

***Presenting Author* |** *Clausell Mathis, University of Washington-Seattle*
Additional Author | Jessica Hernandez, University of Washington - Bothell
Additional Author | Lauren Bauman, University of Washington-Seattle
Additional Author | Ansel Neunzert, University of Washington - Bothell
Additional Author | Amy Robertson D, Seattle Pacific University

In this talk, we share preliminary findings from a study of teachers' ideas about equitable-based instruction and how it can be integrated with energy-focused physics instruction. During a one-week professional development workshop, we observed high school physics teachers' (n=24) conversations focused on formulating ideas to integrate equity and energy within their classroom curriculum, pedagogies, and settings. Data was collected through video recordings and the data analysis was multidimensional. We found that as teachers considered integrating equity into their energy instruction, they raised concerns about relationships with students and about balancing past and present systematic factors. They also articulated a number of strategies and possibilities that they had tried or wanted to try to address these systematic factors This study has implications for merging energy and equity through a culturally-relevant lens that is essential to addressing educational disparities.

B2.5-05 | Physics Club: A Counterspace for Developing Female Students Physics Identity

Presenting Author **|** *Pooneh Sabouri, Florida International University*
Additional Author **|** *Zahra Hazari, Florida International University*

Research shows that by the time female students reach high school age they are much less likely than male students to see themselves as "physics people," which contributes to the persistent underrepresentation of women in physics. To this end, physics teachers can play a critical role in changing young women's negative self-perceptions with respect to physics and help develop their physics identity by disrupting traditional cultural messaging and norms. However, the long existing culture of power in many physics' classrooms may not provide a safe space for female students to enact physics identities in ways that are personally meaningful. Thus, counter spaces beyond existing classrooms are needed to create and sustain such changes. In this study, we describe how an informal physics club initiated by a high school physics teacher and run by his female students has become a counterspace that promotes physics identity development among students, particularly for female students.

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

B2.5-07 | How Goal Endorsement Predicts Physics Identity

Presenting Author **|** *Joineé Taylor, Florida International University*
Presenting Author **|** *T. Blake Head, Florida International University*
Additional Author **|** *Zahra Hazari, Florida International University*

Physics has been perceived as a highly individualistic discipline with little value placed on communal goals. As such, students who have communal goals may not see themselves as "physics people". In this study, we examine the role of agentic goals (focused on self) and communal goals (focused on others) on students' physics identity. As part of the STEP UP project, data was collected in Fall 2018 from the high school physics classes of 16 teachers across three regions of the US. In total, 1, 979 students completed surveys which included questions on their values/goals and physics identity. This talk will present the results of a model used to predict physics identity with agentic and communal goals, while also considering gender and race/ethnicity effects.

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

B2.5-08 | Integrated Physics Identity Performances of BIWOC and LGBTQ+ Women

Presenting Author **|** *Xandria Quichocho, Michigan State University*
Additional Author **|** *Eleanor Close., Texas State University*

Identity development is critical to student retention in physics degree programs. Historically, research on physics identity has been conducted at Predominately White Institutions and has largely ignoring the unique identity intersections experienced by Black, Indigenous, and women of color and women who identify as Lesbian, Gay, Bisexual, Transgender, and Queer. We conducted semi-structured interviews with women who identify within these categories at two Hispanic Serving Institutions in Central Texas. In order to better understand how multiply-marginalized students negotiate their intersectional identities, we adopt the theory of identity as performance. Our analysis focuses on the way students fragment or integrate their social and physics identities and how this may affect their view of themselves as physicists. In this talk, we present a case-study centered around Alexis's narrative describing the thoughtful and intentional performance of her outward appearance in order to gain membership and showcase competence in the undergraduate physics classroom.

B2.06 | Physics Education from Around the World
January 10, 2021 | 2:30 PM - 3:45 PM

Sponsor: *Committee on International Physics Education*
Co-Sponsor: *Committee on Teacher Preparation*

B2.6-01 | Physics Teacher Preparation at Hubei University

Presenting Author **|** *Weining Wu, Hubei University*
Additional Author **|** *Yimin Ding, Hubei University*
Additional Author **|** *Kathleen Falconer, SUNY Buffalo State College*

Both traditional and modern approaches are used to training physics teacher at Hubei University. In traditional ways, we are going to talk about micro-teaching and teaching competition. The former is used for training the basic teaching skills of our normal students, and the latter is used for further training their comprehensive teaching skills. We will focus on the latter, because that is probably special to the US counterparts. In modern approaches, we will focus on the application of digital simulation technique and mobile phone sensor in the process of teacher preparation. The introduction of digital simulation and digital sensor technologies can not only greatly improve the effect of physical experiments, but also improve students' operational ability as well as innovation ability. In addition, as an influential instructional assessment tool, RTOP's practical use in teacher preparation at Hubei University will be introduced.

B2.6-02 | Reflective Practice and Pre-service Physics Teachers' Critical Thinking in Ireland

Presenting Author **|** *Deirdre O'Neill, Dublin City University*
Additional Author **|** *Eilish McLoughlin, Dublin City University*

The essence of student-centered teaching is an awareness of how our students experience learning. Brookfield 2017, highlights that personal experiences of learning are intertwined with teaching practice and considers it as one of the lenses in his critical reflection framework. This study investigates the reflective practice of seven Irish pre-service physics teachers in the final year of their four-year concurrent science education degree. The significant guidance, support and feedback from teacher educators that is required to support deeper levels of critical reflection will be discussed in detail. Thematic analyses of seventy reflective journal entries have been carried out to make connections between themes and build a coherent argument supported by the data. Findings from this qualitative study outline the wider implications of reflective practice on deepening teacher knowledge and professional learning.

B2.6-03 | 02:30 PM - 03:45 PM | A Powerful Factor in Teaching and Learning

Presenting Author **|** *Michael Ponnambalam, University of the West Indies, Jamaica*

A parental care for students works magic – as verified by the feedback I have received from numerous students in many countries. The students' experience of a genuinely caring attitude from the teacher gives them extra energy for their learning-journey. Further, it facilitates relationship and interaction, which are very helpful in the learning process. The famous behavioral scientist Carl Junghas this to say: "The curriculum is so much raw material, but warmth is the vital element for the growing plant and for the soul of the child."

B2.6-04 | Effects of Advanced Teacher Trainings Regarding Diversity Aspects

Presenting Author | *Ann-Katrin Krebs, Paedagogische Hochschule Schwaebisch Gmuend*
Additional Author | Prof. Dr. Lutz Kasper Frank, Paedagogische Hochschule Schwaebisch Gmuend

The project “Teaching MINTD” at the University of Education Schwaebisch Gmuend (Germany) aims for an increase in physics and technology teacher students with a multimethod approach to adapt and complete the current curriculum with diversity oriented and gender sensible contents. To identify appropriate methods and contents in the field the project acquired in-service STEM teachers to look into their current teaching and to develop contents for four special teacher training workshops. The PhD project focuses on the physic teachers and looks into the success of professional development on an individual subjective level with structured guideline interviews after each workshop and surveys the students with a questionnaire about their physic classes. The theoretical background is about the effects of teacher trainings on four levels (Lipowsky & Rzejak, 2012, 2015, 2017). The presentation will show the state of physic classes and first results from the interviews.

B2.6-05 | The New Physics Curriculum in Finnish Upper Secondary School

Presenting Author | *Ari Hämäläinen*

The National core curriculum prepared by the Finnish National Agency of Education is the statutory norm that guides teaching. The revised upper secondary school core curriculum will come into effect in August 2021.According to the new core curriculum, upper secondary school physics consists of eight modules, two of which are compulsory for every student. I will present the contents of the modules and general guidelines behind the curriculum. The physics part of the National Matriculation Exam that tests how the goals set by the core curriculum are met is also discussed briefly. I have worked as an advisor in the planning process of the physics core curriculum, have been preparing problems for the matriculation exam, and currently I belong to a team that will publish a set of textbooks and digital materials following the new standard.

B2.6-06 | An Improved Model for Measuring the Speed of Sound

Presenting Author | *Shiyun Zhou, Fudan University*
Additional Author | Yue Shen, Fudan University

Measuring the speed of sound in water is a typical experiment in undergraduate physics laboratory courses. The resonance of ultrasonic waves can be used to determine the wavelength, thereby calculating the speed of sound. It is generally considered that the ultrasonic wave reflected on the surface of the receiver interferes with the incident ultrasonic wave. Resonance occurs when the distance between the two transducers is an integer multiply of the acoustic half-wavelength. However, the residual distribution of the experimental data and the abnormal raising of receiving signal amplitude show that the simple standing wave model is not enough to describe this experiment. Considering the multiple reflections of ultrasonic waves between the transmitting and receiving transducers, and the reflection of ultrasonic waves on the water-air interface, an improved model is proposed. The simulation results show that the height of the water has a great influence on the abnormal experimental phenomena.

B2.07 | Physics Programs at HSIs/MSIs
January 10, 2021 | 2:30 PM - 3:45 PM

Sponsor: *Committee on Diversity in Physics*
Co-Sponsor: *Committee on Physics in Undergraduate Education*

B2.7-01 | Practical Recommendations for Cultivating Sustained STEM Instructional Change at HSIs

Presenting Author | *Alice Olmstead, Texas State University*
Additional Author | *Eleanor Close, Texas State University*
Additional Author | *Mavreen Tuvilla Rose, Texas State University*
Additional Author | *Brianne Gutmann, Texas State University*
Additional Author | *Egla Ochoa-Madrid, Texas State University*

Higher education institutions play a critical role in preparing students to be future STEM leaders, yet significant inequities remain in which students persist and thrive in STEM. Hispanic Serving Institutions (HSIs) have both an outsized opportunity to support racially minoritized STEM learners and distinctive structural challenges that need to be considered. In this talk, I will share practical recommendations for cultivating lasting STEM instructional change at HSIs. These recommendations are distilled from my experiences designing and starting to implement a $2.5 million college-wide change effort with a team at my home institution, as well as my participation in the institutional change research community. They include the importance of creating a theory of change, coordinating multiple change strategies, drawing on targeted research about supporting racially minoritized learners, forming and building up positive relationships with administrators, fostering communities of practice among faculty and students, and constantly keeping your long-term goals in mind.

Additional authors: Jiwoo An, Cynthia Luxford, Li Feng, and Heather Galloway (Texas State University). This work is supported by NSF #1928696.

B2.7-02 | Progammatic Transformation for Student Success at a Southern California

Presenting Author | *Sara Callori, California State University San Bernardino*

California State University San Bernardino (CSUSB), a HSI located in Southern California's Inland Empire, recently underwent a relatively unique opportunity to transform the physics curriculum as part of the university's transition from quarters to semesters. This afforded our department to take a close look at our student population, learning outcomes, and overall mission in order to create new programs focused on student success and preparing them to enter a variety of fields, serving both local needs and a national priority of diversifying the STEM workforce. In this talk I will detail and reflect on our process of transformation and give specific examples of new courses (e.g. first-year seminar, new upper division labs) or approaches to teaching that we hope will benefit our departmental community. I will also discuss external funding programs and other resources we have tapped into to enhance opportunities available to our students.

B2.8-01PA | Introduction to Zooniverse Citizen Science in Your Classroom
January 10, 2021 | **2:30 PM - 3:45 PM**

B2.8-01 | Introduction to Zooniverse Citizen Science in Your Classroom
Presenting Author **|** *Richard Gelderman, Western Kentucky University*

Zooniverse.org, the popular online citizen science investigations, recently developed a suite of active learning curricular materials incorporating their research experiences for introductory astronomy courses. The in-class activities and group investigations employ custom extensions to Google sheets to provide a student-friendly interface for data analysis and interpretation, all while addressing core astronomy topics (see classroom.zooniverse.org). In the next phase of this effort, Zooniverse received NSF-IUSE funding to work with a national collaboration of astronomy educators and researchers at a range of institutions to enhance all levels of introductory astronomy courses with grade-able activities based on Galaxy Zoo, exoplanet searches, star properties, and planetary science. Participants will gain experience with the available investigations, as well as hear how participation in citizen science impact students' attitudes towards science and scientists, the role of society in science, and their own identity development and potential for lifelong engagement and advocacy.

C1.01 | Teaching the Introductory Physics for the Life Sciences (IPLS) Course
JANUARY 11, 2021 | **10:30 AM - 11:45 AM**
Sponsor: *Committee on Physics in Undergraduate Education*

C1.1-01 | Active Learning in College Physics: It Takes Two to Tango
Presenting Author **|** *Dr. Krassi Lazarova, Centenary University*

This poster presentation focuses on the balanced mix of lecture-based teaching and project-based learning in introductory college physics courses for life science majors. Students naturally resist active learning approaches because they put more responsibility on the learner to master the content. If the lectures still cover the content, the accompanied labs practice the concepts hands-on, and instead of final exams, students are charged with final projects, they apply all of the learned concepts into problem-solving and trouble-shooting with a final product available at the end of the process. Students learn more than the physics concepts: they also learn patience, trial and error, time management, and many other life lessons

C1.1-02 | Modeling the Coronavirus Pandemic in The United States
Presenting Author **|** *Peter Nelson, Post University*

Simple epidemiological models are introduced using finite difference methods in Excel. The resulting SIR model is then fit to published COVID-19 infection rate data for the United States using least-squares techniques. Using their own spreadsheets, students discover that the SIR model explains: the initial exponential growth of COVID-19; the effects of social distancing during April and May 2020; and the summer surge caused by prematurely lifting social distancing. The SIR model is the origin of the basic reproduction number R0 and the concept of herd immunity. A wide range of student research projects are possible to make quantitative predictions based on published data for US states and other countries, including: predicting the benefit of implementing social distancing earlier; predicting how many lives were lost because people didn't wear masks; the nascent fall surge; and the effect of a potential vaccine. See http://circle4.com/biophysics for free textbook chapters and instructional videos.

C1.1-03 | Introductory Physics for Pre-health Students on an Adaptive, Interactive Platform

Presenting Author **|** *Priya Jamkhedkar, Portland State University*
Additional Author **|** *Ralf Jamkhedkar, Portland State University*

Teaching traditional introductory physics courses to pre-health and life science students has been a challenge for students who find it difficult to connect physics concepts with bio-medical applications. This, in addition to, large class sizes, students with diverse skills in math, problem-solving, conceptual reasoning, and learning styles makes it even more challenging. Using biomedical examples, applications, and videos from experts in the bio-medical field throughout the course and providing interactive activities such as simulations, concept questions and problems with scaffolding questions along with support for students with different learning preferences and skill levels has potential to promote active and engaged learning to have a long-lasting impact on the students' educational experience. We will discuss the curricular development and the first all remote implementation of the course on the online platform "Cogbooks". The talk will conclude with our observations and experiences from the first course on mechanics.

This work is supported by the grants DUE- 1624192 and DUE- 1933984 from the National Science Foundation.

C1.1-04 | IPLS – The Physics That Life-Science Students Want and Need

Presenting Author **|** *Peter Nelson, Post University*

The traditional introductory physics course doesn't work for life-science students. Life-science students don't find kinematics or Newton's laws to be relevant to their interests. That, combined with the well-known conceptual problems associated with describing motion mathematically, suggests the need for a new starting point for the Introductory Physics for Life Sciences (IPLS) course. This presentation outlines a new pedagogical approach for life-science students. It starts with the "marble game," which simulates diffusion – a topic students already know is fundamental to biology. Modeling techniques introduced with the marble game are then applied to drug elimination; radioactive decay; osmosis; the Boltzmann factor; ligand binding; thermodynamics, phase equilibrium and entropy; membrane voltage, RC circuits and the action potential; models of COVID-19; and yes, even Newtonian mechanics. I've been successfully using this approach with IPLS students for over 5 years. See http://circle4.com/biophysics for free textbook chapters and instructional videos.

C1.1-05 | Why I teach Psychology on IPLS Day 1

Presenting Author **|** *Edward Redish, University of Maryland*

An important learning goal for IPLS students is to have them see physics as a way of learning reasoning rather than facts. Unfortunately, many students expect the latter and resist the former. The most critical step is to shift them away from "answer making" to "sense making." A good way is to elicit a mistake, confront it, and scaffold a resolution [1] But if students see mistakes as shameful instead of an opportunity to learn, this approach can result in strong negative reactions. I frame the class as "reasoning not answers" on the first day by teaching basic psychological principles of memory and decision making [2] using common surprising illusions. I introduce mantras that we use throughout including [3]: "one-step thinking", "missing the gorilla", and "debugging your thinking." These help students begin to see errors as valuable learning tools instead of as an embarrassment and to engage with sense-making.

[1] L. C. McDermott, Millikan Lecture 1990: What we teach and what is learned, closing the gap, Am. J. Phys. 59:4 (1991) 301-315. [2] D. Kahnemann, Thinking Fast and Slow (Farrar, Strauss, & Giroux, 2011); A. D. Redish, The Mind within the Brain: How we make decisions and how those decisions go wrong (Oxford U. Press, 2015). [3] E. F. Redish, Oersted Lecture 2013: How should we think about how our students think? Am. J. Phys. 82:6 (2014) 537-551.

C1.1-06 | Back to School: Physicists Learning the Life Sciences for IPLS

Presenting Author **|** *Brad Moser, Hamilton College*

Transforming an introductory physics class to meet the needs of life science majors is no easy task. It requires curiosity, humility, dedication, and a willingness to be a novice learner again. Honestly, it may not be for everyone. But for those educators who are willing and able to undergo this reform, the rewards of a deep connection with life science students and pre-health professionals are immensely satisfying. In this talk I highlight my experiences reforming the introductory class at a former university, the resources and educators who were most influential, and the early stages of my quest to bring an IPLS class to my current college. Finally, I share a new podcast that I just released called Physics Alive*, where I interview PER and IPLS instructors and researchers. This podcast provides an opportunity for listeners to discover new ideas and even use episodes in their classrooms. *https://physicsalive.com/

C1.1-07 | Mining Biological Research when Developing Curricular Materials for Introductory Physics

Presenting Author **|** *Melissa Vigil, Marquette University*

One challenge when teaching physics to life science students is that they do not see the connections between physics and their other coursework. Additionally, some teachers of introductory physics believe that PER-based tools such as motion maps and energy graphs are not used aside of physics class and so they focus on algebraic problem-solving algorithms. I have found that including work from recent experimental biology in introductory physics courses can both provide relevance to bio-focused students and show physics faculty colleagues that the multiple representations used by PER informed textbook authors are used actively and effectively in current biological and biomedical contexts. Several examples from applications as diverse as bio-mechanical engineering, ethology, and molecular biology will be discussed to highlight where to look for good examples and how to incorporate such materials in introductory courses.

C1.1-08 |Students own biomechanics scenarios with digital practice and screencast feedback

***Presenting Author* |** *Nancy Beverly, Mercy College*

In the online environment, we are encouraged to find ways to assess student progress that are resistant to online cheating, and also provide an especially supportive environment for learning in these challenging times. Our first semester IPLS course, serving a pre-PT and exercise science population, focuses heavily on biomechanics. After digital practice with provided biomechanics scenarios, focusing on different aspects every week, students work on those aspects in scenarios of their own. These weekly scenario digital submissions are submitted as drafts and feedback is given in screencasts going over their work. The subsequent revisions are what is assessed for competence in the learning outcomes of the course

C1.02 | Astronomy Posters

JANUARY 11, 2021 | **10:30 AM - 11:45 AM**

C1.2-01 | 10:30 AM - 11:45 AM | Web-based Astronomy Coding Labs

***Presenting Author* |** *James Newland, University of Houston*

Bringing computational thinking into the science classroom is more important than ever. Here we look at a series of web-based astronomy lab activities that use modern computing and data science paradigms to process authentic datasets that ask students to investigate underlying phenomena using inquiry and exploration. These activities work when students are learning face to face or when doing remote learning. Google CoLab means access to a high-quality Python programming environment that allows for collaboration between students while eliminating the daunting learning curve associated with setting up a programming environment. Modern data science techniques for analysis and visualization appear throughout the activities where appropriate.

C1.2-02 | Densities of Extra Solar Planets

***Presenting Author* |** *Michael LoPresto, University of Michigan*
Additional Author | *Alex Alajbegovic, University of Michigan*
Additional Author | *Alyssa Russell, University of Michigan*

Most of the exoplanets discovered by the Kepler mission were detected by the transit method, which gives the radius of the planet. Use of the radial velocity or Doppler-detection method gave us the mass for a number of these planets which allows their densities to be determined. Comparison of these densities to the densities of the planets considered to be of similar type based on radii in our own solar system shows that some exoplanets of similar size to low-density “ice-giants, ” like Uranus or Neptune, have greater densities more like the smaller, rock-metalterrestrialor Earth-like planets of our solar system and that the reverse is true; that some smaller, more Earth-sized, exoplanets have lower-densities more similar to the larger ice and gas giants in our solar system.

C1.2-03 | Angular Momentum of Astronauts, Hurricanes, and Sunspots

Presenting Author **|** *Lorin Millet, Emeritus Professor, California State University, Chico*

An astronaut floating at rest in Skylab and a hurricane floating over a very smooth ocean are similar. The astronaut can suddenly rotate arms, but torso also moves and total angular momentum stays zero. The hurricane can begin spinning, but it also orbits in the opposite direction and total angular momentum stays zero. It is wrong to think that a hurricane has only spin angular momentum. It is also wrong to think that they are blown west by trade winds. They move west because the earth is a sphere and the Coriolis force is proportional to the sine of the lattitude angle. This, and Bernoulli's principle makes them also move poleward, again because the earth is a sphere. The existence and motion of hurricanes demonstrates that the earth spins and is spherical. Application of what we know about the formation and motion of hurricanes, applied to sunspots yields new insight.

C1.2-04 | Physics in an Astronomy Context: Resources from the NASA SSEC

Presenting Author **|** *Rebecca Vieyra, University of Maryland*
Presenting Author **|** *Brad Ambrose, Grand Valley State University*
Presenting Author **|** *Janelle Bailey, Temple University*
Presenting Author **|** *Ximena Cid, California State University - Dominguez Hills*
Presenting Author **|** *Ramon Lopez, University of Texas at Arlington*
Presenting Author **|** *Shannon Willoughby, Montana State University*

Learn about 19 different physics activities embedded into an astronomy context developed by the Temple/AAPT team of the NASA Space Science Education Consortium. Many of these materials can be incorporated into an online learning environment. Activities cover topics as wide-reaching as spectroscopy and the likelihood of identifying life in outer space, periodic relationships and solar activity, electromagnetism and auroral currents, motion graphs and coronal mass ejections, and geometric optics and solar eclipses.

C1.2-05 | Evolution of the Journal of Astronomy & Earth Sciences Education

Presenting Author **|** *Timothy Slater, University of Wyoming*

Filling an important niche in the discipline-based science education research domain, the Journal of Astronomy & Earth Sciences Education JAESE is entering its 8th year. Initially started to fill the gap left by the termination of the Astronomy Education Review journal, JAESE publishes education-based research studies across the broad field of Earth, space, and planetary sciences including the disciplines of astronomy, climate education, energy resource science, environmental science, geology, geography, agriculture, meteorology, planetary sciences, and oceanography education. JAESE uses a double, blind-peer review process to insure the scholarly quality of the astronomy education research studies published. Moreover, JAESE uses an open-access financial model where nominal open-access costs are charged to authors and institutions rather than annual memberships, large library subscriptions, or expensive “gold” open-access fees.

http://jaese.org

C1.03 | Labs/Apparatus Posters
JANUARY 11, 2021 | **10:30 AM - 11:45 AM**

C1.3-01 | 10:30 AM - 11:45 AM | Discovering Buoyancy as an Open-ended Lab
Presenting Author **|** *David Waters, University of Health Sciences and Pharmacy in St. Louis*
Additional Author | Anthony Wilmes, University of Health Sciences and Pharmacy in St. Louis

For the past few years, the fall semester algebra-based introductory physics labs have been teaching skills alongside content. We instruct students on how to create models and how to use those models to answer experimental questions. When a student is presented with an experimental question, they are given minimal assistance and must design their own experiment based on prior knowledge. For our lab on buoyancy, we introduce the topic in lab first before going into more detail in the lecture. The end goal is for students to discover that the buoyant force is equal to the weight of the water displaced. Students then analyze the results of their experiment and compare class data using a t-test, another learned skill. We present this discovery lab to give others ideas for new labs that can be done in courses involving physics for the life sciences.

C1.3-02 | An Advanced Lab on the Quantum Pendulum
Presenting Author **|** *Enrique Galvez, Colgate University*
Additional Author | Jake Freedman M, Colgate University
Additional Author | Anupama Motee, Colgate University
Additional Author | Yingsi Qin, Colgate University

The wave equation for electromagnetic waves, the Helmholtz equation, has the same form as the Schrodinger equation of quantum mechanics. We present the generation of optical beams in Mathieu modes, whose angular solution is the same as the wavefunction for the quantized pendulum. The light in such a mode is generated by a spatial light modulator and imaged by digital cameras. The intensity of the light in the far field is proportional to the probability of finding the pendulum bob as a function of angle. In this experiment students can investigate, quantization, wavefunction symmetry, probabilities and explore non-classical aspects of the quantum solutions. Superpositions can also produce wave-packets that resemble the classical motion. We also focus on states that approximate the harmonic oscillator.

C1.3-03 | 10:30 AM - 11:45 AM | Experimental study on the Viscosity of Fliuids
Presenting Author **|** *Shihong MA, 1. Department of Physics, Fudan University, Shanghai, China; 2. Shanghai Center for Physics Education and Teaching Research, Shanghai, China*
Additional Author | Tianlun YU, Department of Physics, Fudan University, Shanghai , China

Based on the falling ball and capillary tube methods, an apparatus was designed to measure the viscosity of fluids with Poiseuille formula. By changing the circular tubes, the measurement range of 10-3-100Pa scould be achieved. The viscosity of water and CMC liquor at a certain temperature was measured, the results were in accordance with those reported in the references.

C1.3-04 | A virtual Helmholtz Resonator lab

Presenting Author **|** *Earl Blodgett, University of Wisconsin-River Falls*

My upper level Acoustics course was thrust into virtual mode. I designed a “do this at home” lab exercise which my students could perform with readily available equipment found at home. We did a quick study of the Helmholtz Resonator by using an empty 2 L soda bottle, a measuring cup, a ruler and a smartphone. By measuring the frequency with different amounts of water in the bottle, the students were able to extract a good value for the volume of the empty bottle from their graphical analysis of the data. (Many of them were surprised to discover that it is NOT 2.0 L.) As an assessment of their ability to extend the analysis, an exam question provided them with data for a small pendant-style ocarina, from which they were able to deduce the interior volume of the ocarina. Both the lab and the extension will be described.

C1.04 | Physics Education Research I Posters

JANUARY 11 2021 | **10:30 AM - 11:45 AM**

C1.4-01 | Quantum Interactive Learning Tutorial on Larmor Precession of Spin

Presenting Author **|** *Chandralekha Singh, University of Pittsburgh*
Additional Author | Benjamin Brown, University of Pittsburgh

We conducted research on student difficulties used it as a guide to develop, validate and evaluate a quantum interactive learning tutorial (QuILT) on Larmor precession of spin to help students learn about time-dependence of expectation values in quantum mechanics. The QuILT builds on students' prior knowledge and strives to help them develop a good knowledge structure of relevant concepts. It adapts visualization tools to help students develop intuition about these topics and focuses on helping students integrate qualitative and quantitative understanding. Here, we summarize the development, validation and in-class evaluation. We thank the National Science Foundation for support.

C1.4-02 | 10:30 AM - 11:45 AM | Just-in-Time Teaching and Peer Instruction Using Clickers in Quantum Mechanics

Presenting Author **|** *Chandralekha Singh, University of Pittsburgh*
Additional Author | Ryan Sayer, Bemidji State University
Additional Author | Emily Marshman, CCAC, Pittsburgh

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.

C1.4-03 | A 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.

C1.4-04 | Quantum Interactive Learning Tutorial on Mach-Zehnder Interferometer with Single Photons

Presenting Author **|** *Chandralekha Singh, University of Pittsburgh*
Additional Author **|** *Emily Marshman, CCAC, Pittsburgh*

We developed and validated a Quantum Interactive Learning Tutorial (QuILT) on Mach-Zehnder Interferometer with single photons to expose upper-level students in quantum mechanics courses to contemporary applications. The QuILT strives to help students develop the ability to apply fundamental quantum principles to physical situations and explore differences between classical and quantum ideas. The QuILT adapts visualization tools to help students build physical intuition about quantum phenomena and focuses on helping them integrate qualitative and quantitative understandings. Findings will be presented from in-class implementation of the research-validated QuILT. We thank the National Science Foundation for support.

C1.4-05 | What Physics Education Researchers Needs to Know About Psychometrics

Presenting Author **|** *Rebecca Lindell, Tiliadal STEM Education: Solutions for Higher Ed*

All measurements used in education should be fair, reliable and valid. Psychometrics is the field of study that concerns itself with the development of these measurements. Specifically, psychometricians develop theories of measurement of both the development of instrument assessing individuals' skills, abilities, attitudes and educational knowledge, as well as the general test theory behind said development. Psychometrics should guide the development of all measurements undertaken as part of education including classroom tests, quizzes and any other quantitative data collected as part of normal courses as well as the research-based assessments, such as conceptual learning assessment instruments (RbCLAIs). Unfortunately, the theory and methods of psychometrics are not well known or understood. In this poster, I will present the basics of psychometrics as well as common misunderstandings of the psychometrics involved in the development of RBCLAIs.

C1.4-06 | Bridging Physics and Health Sciences through Applied Research.

Presenting Author **|** *Simona Carrubba, Mercyhurst University*
Additional Author | Paul Ashcraft, Mercyhurst University
Additional Author | Joseph Johnson, Mercyhurst University

The Physics Department at Mercyhurst University is aiming at evolving its research directions to provide attracting interdisciplinary opportunities for our students interested in pre-med and pre-health programs. One promising approach involves the use of electroencephalography, a noninvasive electrophysiological method to record brain electrical activity in human subjects from standardized scalp locations (the electroencephalogram or EEG). The EEG consists of a time-dependent voltage that reflects the dynamical electrical interactions occurring among spatially distributed neuronal networks that mediate sensory processing and cognition. Our students developed a series of studies to investigate up-to-date topics in neuroscience including learning and brain plasticity, mental imaginary and cognition, music and emotions.

C1.05 | Lecture and Classroom Posters

JANUARY 11 2021 | **10:30 AM - 11:45 AM**

C1.5-01 | Developing Augmented Reality Modules to Teach Torque

Presenting Author **|** *Nick Giordano, Siena College*
Presenting Author | Adam Lenard P, Siena College
Presenting Author | Kyle Tessier C, Siena College
Additional Author | Michele McColgan, Siena College

Most students find difficulty in visualizing 3D concepts in physics courses. Some of these include torque, circular motion, and moment of inertia. A solution to this issue is to present these concepts in augmented reality to allow for better visualization of them. The augmented reality activities presented in this project were created by a team of undergraduate physics and computer science students using the software Unity and the Merge Cube. We present a systematic process of creating and improving specialized apps that can be utilized in a classroom environment.

C1.5-02 | Impact of Torque and Rotation Tutorial on Student Problem-Solving Abilities

Presenting Author **|** *Kathleen Koenig, University of Cincinnati*
Additional Author | Alexandru Maries, University of Cincinnati
Additional Author | Robert Teese, Rochester Institute of Technology
Additional Author | Michelle Chabot, Rochester Institute of Technology

This poster will showcase one of our Interactive video-enhanced tutorials (IVETs). IVETs involve web-based activities that lead students through a solution using expert-like problem-solving approaches. Under NSF funding we have developed and evaluated multiple IVETs for use with college students in introductory physics. This presentation will showcase one of our IVETs, namely Torque and Rotation, and provide details about its design features, which involve multimedia principles of learning and research on human learning and memory. TheIVET's impact on student problem-solving abilities will also be shared.

**Work supported by the NSF IUSE Program (DUE #1821396)*

C1.5-03 | Using Desmos for Interactive Visualizations of Physics: Wave-Interference

Presenting Author **|** *Roberto Salgado, Minnesota State University Moorhead*

I describe the sequential development of an animated Desmos visualization of the wave-interference from two point-sources. Starting with static wavefronts with tunable parameters, I compute the superposition to obtain an interference pattern in the plane. I then introduce a screen where I compute the instantaneous waveform and power, then the time-averaged power. Along the way, I'll share some Desmos tricks I learned in the process.

I contributed a more general survey of my Desmos visualizations to the session on Effective Practices in Educational Technology.

C1.5-04 | Using Bloom's Taxonomy to Develop New Assessments

Presenting Author **|** *David Waters, University of Health Sciences in St. Louis*
Additional Author | Margaret Weck, University of Health Sciences in St. Louis

In our algebra-based introductory physics sequence, we have had exams consisting of multiple-choice questions and traditional math problems. The multiple-choice questions were more conceptual in nature and would come at the beginning of our exams. Then we would have all of the math problems. Unfortunately, a single multiple-choice question that potentially covers a number of topics at an arbitrary level of difficulty doesn't allow an instructor to determine a student's level of understanding of any single topic. To better assess students' levels of understanding, we designed sets of questions and problems with increasing difficulty, as defined by Bloom's Taxonomy. This new way of structuring exams benefited the instructor in documenting levels of student understanding. It also allowed weaker students to show mastery at some level and possibly boost their confidence with the more challenging questions. In general, the students have rated this new assessment positively.

C1.5-05 | Determining the Affect That Study Methods Have on Exam Scores

Presenting Author **|** *David Waters, University of Health Sciences and Pharmacy in St. Louis*
Additional Author | Rahul Jilakara, University of Health Sciences and Pharmacy in St. Louis

In our algebra-based introductory physics sequence, we have exams that consist of multiple choice and traditional math problems. Students were able to solve the math problems as well as expected, but found multiple choice questions to be more challenging. Students often asked for an optimal way to study for these questions, but we weren't sure how to answer. So we set out to investigate how students were studying for these exams and how those study habits changed as they progressed through the course. After three years of data collection, we have insight into the ways students prepare for introductory physics exams, how they perceive these study methods to have affected their exam scores, and the study methods actual exam helpfulness. Our hope is to help our current students succeed in the course by introducing them to study methods that have shown to be effective in the past.

C1.5-06 | Real-world Problems for AP® Physics 1 and AP® Physics 2.

Presenting Author **|** *Eric Strong, School for the Talented and Gifted*

Breaking free from the traditional "cart on a ramp" problem, this session presents a variety of real-world, aviation related, physics-based problems. Focused on the general aviation aircraft, both single-engine and multi-engine, the problems expose the student to application of physics in aviation. The problems span a range of difficulties from simple trigonometry and simple unit conversion problems to more complicated thermodynamic and forces on an airplane problem. The problems come from the aviation world, including examples from aircraft instrument approaches, aircraft turbocharger operations, aircraft drag force in various flying configurations, and asymmetrical thrust in multi-engine airplanes. These problems are targeted to the student in a first year, algebra-based physics course such as AP® Physics 1 and AP® Physics 2.

C1.06 | Physics Education Research II Posters

JANUARY 11, 2021 | **10:30 AM - 11:45 AM**

C1.6-01 | Empowering Women in Physics: Forming Identity Through Outreach and Engagement

Presenting Author **|** *Emily Hay, Texas A&M University*
Presenting Author | *Jessi Randolph, Texas A&M University*
Additional Author | *Jonan Donaldson,*
Additional Author | *Jonathan Perry, The University of Texas at Austin*
Additional Author | *Tatiana Erukhimova, Texas A&M University*

We employed a student-centered approach to examining the impact of physics outreach on female undergraduate and graduate student volunteers. We conducted a series of interviews with current and former female students who facilitated physics outreach programs at Texas A&M University. We focused on how the individual experience of these students related to their formation of physics identity, recognition, and self-efficacy. We also report on the development of soft skills gained through outreach opportunities and their link to increases in motivation, confidence, and self-perceptions of becoming more expert in the field.

C1.6-02 | A Virtual Physics Lab to Educate the Public About Radiation

***Presenting Author* |** *Jia Jing, Hefei University of Technology*
Additional Author | Ting Zhang, Hefei University of Technology
Additional Author | Hui Lin, Hefei University of Technology

Explaining the field of Radiation Physics to the public is a hard task. It is essential to foster techniques to make this field approachable and understood to the layman. According to the characteristics of related radiation physics contents, it expounded and illustrated the role and advantages of computer simulation technology. Viewers become familiar with the Virtual Physics Lab and can follow along with the different story lines. Those include modern physics illustrations in the categories of x-ray, Imaging and radiation detection. Computer simulation technology is applied in the recurring of physical process, the interpretation of physical principles and the simulation demonstration in experiment teaching. It can make some physical problems which are gradual, dynamic and abstract transform into the visual, imaged and vivid physical scenes. Applying computer simulation technology in the teaching process can greatly change the traditional teaching and learning concepts, enhance the layman to better understand the abstract radiation physics theories.

The authors thank the sponsorship of teaching research project of education bureau of Anhui province, China (2018JYXM1001) and the demonstration project of education informationization in Hefei University of Technology (KCXX1904).

C1.6-03 | URM Grouping Hides Struggles of Black and Asian American Students

***Presenting Author* |** *Devyn Shafer, University of Illinois at Urbana-Champaign*
Additional Author | Maggie Mahmood S., University of Illinois at Urbana-Champaign
Additional Author | Tim Stelzer, University of Illinois at Urbana-Champaign

We conducted a series of multiple linear regressions to examine the predictive ability of race on introductory mechanics final exam scores when controlling for ACT math scores and physics placement test scores. When we followed a common method of categorizing students as URMs and non-URMS for our analysis, we found that students who earned comparable scores on the ACT math test and the physics placement test performed similarly on the final exam. However, when we established separate groups for Non-Hispanic White American, Asian American, African American, Hispanic, International, Multi-Race, AIAN, and NHPI students, we found that African American and Asian American students, and to a lesser extent, Hispanic students, under-performed in their physics course relative to their prior test scores. We conclude that there is still work to be done at the university level to provide a learning environment supportive of students of all backgrounds.

C1.6-04 | Addressing Rare Outcomes in PER Quantitative Studies

Presenting Author **|** *Nicholas Young, Michigan State University*
Additional Author **|** *Marcos Caballero D., Michigan State University, University of Oslo*

We encounter variables with little variation often in PER due to the demographics of physics and the questions we ask. For example, in course completion studies, most students will earn high enough grades to pass the course. Yet, little work has examined how to analyze such data. Therefore, we conducted a simulation study using logistic regression, penalized regression, and random forest. We systematically varied the fraction of positive outcomes, feature imbalances, and odds ratios. We find the algorithms treat features with the same odds ratios differently based on their imbalance and the outcome imbalance. While none of the algorithms solved the problem, some reduced the scale of the problem. Our results suggest that PER studies may contain false negatives when determining which variables are related to an outcome. We propose recommendations for researchers and then illustrate these by predicting which applicants will be admitted to a graduate physics program.

C1.6-05 | Retaining Underrepresented Students through Outreach Programs: A Systematic Literature Review

Presenting Author **|** *Madison Swirtz, Colorado School of Mines*
Additional Author **|** *Simone Hyater-Adams, American Physical Society*
Additional Author **|** *Claudia Fracchiolla, American Physical Society*

There is a good deal of focus on recruiting underrepresented students to study physics at the collegiate level, but a lack of focus on how to make sure they are being recruited into a welcoming and safe environment that values their identity. Because of this, underrepresented students tend to feel a disconnect from the physics community and are more likely to drop out or switch majors. One potential method of combating this issue is increasing the peer networks of these students through informal outreach programs, which give students a sense of purpose, belonging, and confidence in physics. This systematic literature review synthesizes studies on the effects of informal STEM programs on the facilitators and identifies gaps in this research as it pertains to underrepresented students.

C1.6-06 | Development of Classroom-Interaction Coding Schemes for PCK Assessment

Presenting Author **|** *Kyle Wipfli, Texas Tech University*
Additional Author **|** *Jianlan Wang, Texas Tech University*
Additional Author **|** *Beth Thacker, Texas Tech University*
Additional Author **|** *Stephanie Hart, Texas Tech University*

As part of a larger project to develop a written instrument to evaluate pedagogical content knowledge (PCK), we are observing classroom interactions between students and student assistants. When observing student assistants, two coding schemes emerged. The first coding scheme was developed to describe the student assistant's ability to guide students through a requested task. The second coding scheme was developed to describe the ability of the student assistant to help students work through their own thought development process. In my poster I will present the two coding schemes, go over the similarities/differences and discuss the future plans for the schemes. The two coding schemes will be used to help design the written PCK instrument.

C1.6-07 | Lost in Translation: Reflecting on the Communication of Instructional Philosophy

Presenting Author **|** *Alia Hamdan, University of Arizona*
Additional Author | Sanlyn Buxner, University of Arizona

As our lives have taken a sharp turn to the unknown, we have been forced to a stop. In this time of uncertainty, we have an opportunity to reflect on our learning goals and how we engage students for meaningful learning. We are currently extending the accumulation of research in physics education which focuses on instruction practices and the mismatch between theory and implementation. We are collecting course syllabi from undergraduate instructors who teach all levels of physics courses. Syllabi are being analyzed for aspects of learner-centered philosophy and practices to help understand how the shift in instructors' intentions is reflected to students. Please contribute if you have taught physics in the last decade! This work will shed light on the current state of instructional practices within the US. Next we will be interviewing select instructors to gain a better understanding of the difficulties encountered while implementing research-based instructional strategies.

C1.6-08 | Educational Approach to Active Circuits for Vacuum Tube Langmuir Probes

Presenting Author **|** *Philip Andrango, Illinois Wesleyan University*

Asynchronous learning has produced challenges to developing technical work of physics students. Building circuits from modules that can be utilized in remote learning is a method for which educators have mandated students to purchase. This paper utilizes a similar notion of creating modules with limiting the components to differential amplifiers, inverting amplifiers, and push-pull circuits. Specifically making components from LM741 operational amplifier or general-purpose components engages students with replaceable components to create active circuits for a distributable experiment. Vacuum tubes utilize the same physical principles as Langmuir probes and are ideal for compact plasma experiments in conjunction with the active circuit modules. Developing active probe circuits is a method for which the technical aspect of physics research can be taught in an asynchronous learning environment.

C1.7 | Paradigms in Physics Potpourri

JANUARY 11, 2021 | **10:30 AM - 11:45 AM**

C1.7-01 | The Partial Derivative Machine

Presenting Author **|** *Michael Vignal, University of Colorado Boulder*
Additional Author | David Roundy, Oregon State University

Developed at Oregon State University, the Partial Derivative Machine (PDM) is a mechanical analogue to a thermodynamic system that allows students to explore the mathematics of thermodynamics through the more familiar physics of a mechanical system with masses and strings. The PDM has been used to help students learn about partial derivatives, conjugate variables, state variables, collecting experimental data, processes, cycles, and more! This poster will outline uses and benefits of the PDM as well as expand on a few possibilities for using the PDM in the classroom.

C1.7-02 | 10:30 AM - 11:45 AM | Structural Features of External Representation in Physics

Presenting Author **|** *Elizabeth Gire, Oregon State University*
Additional Author | Edward Price, California State University San Marcos
Additional Author | Corinne Manogue, Oregon State University
Additional Author | Tevian Dray, Oregon State University
Additional Author | Charles de Leone, California State University San Marcos

External representations play a vital role in doing and learning physics. At this poster, we will discuss a new framework for describing external representations and implications for teaching. First, we identify three aspects that distinguish one representation from another: the conceptual referent, the medium of the representation, and how information is organized in the representation. We then identify structural features of representations that take into account both the form and the function of the representation. We will illustrate this framework of structural features with some examples, including plastic "surface" models of 2D functions and an "arms" representation of quantum states. Based on this framework, we suggest strategies for helping students learn to interpret and use external representations. \

C1.7-03 | New Curricular Materials Website/Quantum Learning Progression

Presenting Author **|** *Corinne Manogue, Oregon State University*
Additional Author | Tevian Dray, Oregon State University
Additional Author | Elizabeth Gire, Oregon State University
Additional Author | Maggie Greenwood, Oregon State University
Additional Author | David Roundy, Oregon State University

The Paradigms in Physics group at Oregon State University is premiering a new dissemination website, https://paradigms.oregonstate.edu. This "poster" will be a guided tour of the new site which includes activities for many upper-division courses, sequences of activities, and homework problems. All of these components have been classroom tested over a number of years in the Paradigms Program and a number of them have been the subject of formal PER studies. You will also find advice about how to facilitate different styles of activities including small group problem solving, kinesthetic activities, visualization activities, and activities using dry-erasable plastic surfaces from the Raising Physics to the Surface project. In addition, we will demonstrate flow charts that demonstrate our learning progression of content for quantum mechanics.

Supported in part by NSF grants DUE 1836603, 1836604.

C1.7-04 | 10:30 AM - 11:45 AM | Embodying Complex Numbers and Quantum States

Presenting Author **|** *Kelby Hahn, Oregon State University*
Additional Author | Elizabeth Gire, Oregon State University

The Paradigms @ OSU team has developed a series of activities that supports students in reasoning about complex numbers by having students act out those numbers with their arms. The Arms representation is versatile and can be expanded, by grouping students, to include complex-valued vectors. This expansion enables groups of students to represent quantum mechanical state vectors with their arms. The Arms Sequence of activities parallels the progression of OSU's spins-first approach by starting with complex numbers, advancing through two- and three-state systems, considering time-dependence, and eventually extending to approximate wavefunctions. In this poster we will present Arms as a representation and discuss some of the advantages and disadvantages of using Arms to teach quantum mechanics. We will discuss the development of mathematical and physics ideas, cognitive and pedagogical affordances, movement logistics, and the implicit elements of the representation.

C1.7-05 | Surface Models and Multiple External Representations in Paradigms

Presenting Author **|** *Jonathan Alfson, Oregon State University*
Additional Author | Paul Emigh J, Oregon State University
Additional Author | Aaron Wangberg, Winona State University
Additional Author | Robyn Wangberg, Saint Mary's University of Minnesota
Additional Author | Elizabeth Gire, Oregon State University

The Paradigms in Physics program often incorporates activities that encourage exploration of multiple representations simultaneously. In this poster, we discuss an electrostatics activity that occurs near the beginning of the Static Fields Paradigm. We detail one group's use of multiple representations, including a plastic surface model of the potential due to an electric quadrupole. Our analysis examines the features and functions of the external representations, as well as the order in which the representations were provided to the students. We specifically answer the question of how the representations supported inquiry during this activity.

C1.7-06 | Classical Education Touchstones for the Physics Classroom

Presenting Author **|** *Paul Hosmer, Hillsdale College*
Additional Author | Anna Cannon, Hillsdale College

What makes a physics course uniquely “Classical” in the context of the growing Classical Education movement? From high school physics to liberal arts college core physics, are there particular topics, components, or pedagogies, that must be present in a physics classroom to make it uniquely “Classical”? Does physics in Classical Education require teaching from a particular view of science? Does the “Classical” aspect of the course come in the structure (Trivium cycles, classical Quadrivium framework) or is it simply “traditional” physics with classical pedagogy and classical touchstones incorporated? If so, what are the important classical touchstones? We explore and summarize what authors speaking about physics from within the Classical Education movement say concerning what might make a physics course uniquely “Classical”.

C1.7-07 | Design Tactics for Adapting the Ring Cycle in Secondary Implementations

Presenting Author **|** *Edward Price, California State University San Marcos*
Additional Author | Corinne Manogue, Oregon State University
Additional Author | Mary Bridget Kustusch, DePaul University

This poster describes how design tactics can be used to adapt activities developed for the Paradigms in Physics program to other settings. Design tactics provide practical guidance for developers in designing (and refining) curricular materials in order to meet their specific learning goals. More specific than design principles, design tactics are practical and closely guide specific development processes. We describe the role of design tactics in the context of the ring cycle, a sequence of in-class activities on upper-division electromagnetic theory developed as part of the Paradigms in Physics program. We illustrate how design tactics can be used to adapt activities to different formats and align them with available class components (e.g. small group activity, lecture, Zoom session, homework). By contrasting the original implementation at OSU with two secondary implementations at other universities, we illustrate how design tactics can also be used to adapt activities to different settings.

This work was supported in part by NSF Grants No. 1323800 and No. 1836603

C1.7-08 | Development and Design of a Computational Physics Lab Course

Presenting Author **|** *Christian Solorio, Oregon State University*
Additional Author **|** *David Roundy, Oregon State University*

Computational physics courses are becoming an integral part of the undergraduate physics curriculum because they prepare students for their post-baccalaureate career where computational skills are applicable to research and industry jobs. The instruction of computational physics courses varies greatly based on curricular requirements and departmental resources. At Oregon State University, the computational courses are a project-driven laboratory experience. The computational physics lab course is strongly related to the content delivered in the junior-level lecture courses, but they are taught by different instructors so that a non-computational physicist can still deliver the lecture material. In the computational physics lab course, students solve physics problems related to lecture course content using Python and pair programming, a coding technique shown to improve code quality and learning outcomes. We will present the design choices of using the lab structure and the coordination with lecture courses, and the development of the computational physics lab course.

C1.7-09 | A Sensemaking Foundation for Paradigms in Physics at OSU

Presenting Author **|** *MacKenzie Lenz, University of Utah*
Additional Author **|** *Kelby Hahn, Oregon State University*
Additional Author **|** *Elizabeth Gire, Oregon State University*

Sensemaking is a skill valued in the physics classroom as it aids students and expert physicists in drawing connections between varying representations and concepts in order to make sense of what they are learning or teaching. To promote students’ use of sensemaking practices throughout The Paradigms in Physics program we designed a course to explicitly teach students sensemaking skills early in their physics curriculum, Techniques of Theoretical Mechanics. This course covers both classical mechanics and special relativity, giving students experience with sensemaking in two different contexts. By teaching sensemaking explicitly and early, students have a tool box of sensemaking skills to draw on when solving novel physics problems. In this poster we explain the different pedagogical strategies used in Theoretical Mechanics to expand students’ views about sensemaking and help them develop habits that persist throughout The Paradigms in Physics program.

C1.08 | Teacher Training/Enhancement Posters
JANUARY 11, 2021 | **10:30 AM - 11:45 AM**

C1.8-01 | Selecting and Switching STEM Majors at USAF: Associated Retention Factors
Presenting Author **|** *Wilson Gonzalez-Espada, Morehead State University*
Additional Author | Lachlan Belcher, Center for Physics Education Research, Department of Physics, USAF Academy, Colorado Springs, CO
Additional Author | David Meier, Center for Physics Education Research, Department of Physics, USAF Academy, Colorado Springs, CO

At the USAF Academy, 36.4% of the cadets who intended to major in STEM before their first semester ended up graduating in a nonSTEM career. This study investigated factors associated with cadets declaring STEM majors or switching out of them. Of the 3, 248 cadets with a declared major at the end of the academic year, 128 switched majors, with the most cadets switching within either STEM or nonSTEM. Twenty-four cadets switched out of STEM, and seven switched into STEM. STEM departers were more likely to have a low GPA and to come from a preparatory school, and were less likely to be scholars, international or ESL students. Cadets who went from undeclared to STEM majors were more likely to have higher Core GPA and SAT scores and were less likely to participate in athletics. STEM attrition must be addressed through academic support and advising before cadets declare a major.

C1.8-02 | NextGen PET Oriented Canvas Rubric for Online Elementary Education Majors
Presenting Author **|** *Travis Orloff, Los Angeles Pierce College*

The idea of Peer Review is inherent to NextGen PET. Many problems within the curriculum propose a conversation between students where each students defend a different idea. In these cases NextGen PET provides a specific method on how to evaluate the ideas of these hypothetical students. Step 1) Is the information accurate? Step 2) Are all aspects of the argument presented? Step 3) Is the argument presented in a logical way? This semester I wanted to apply this kind of framework as a type of Canvas assignment called Peer Review. Students must complete a rubric regarding a randomly assigned peer's ideas in order to help teach how to evaluate the ideas of others in group discussions. I will present how to set up in the assignments in a Canvas environment and lessons learned during the Fall 2020 semester at Los Angeles Pierce College.

C1.8-03 | Physics Experiment Teaching Case sharing in COVID-19 Pandemic
Presenting Author **|** *Cuiqin Bai, Fudan University*
Additional Author | Yan Cen, Fudan University
Additional Author | Shiyun Zhou, Fudan University
Additional Author | Yuanjie Chen, Fudan University

The start of the spring semester 2020 for universities all over China was postponed due to the coronavirus outbreak. The team of Fudan Physics Teaching Lab actively explored new mode in Physics-experiment teaching for sophomore in special period. We divided the course content into several modules and adopted different teaching methods according to the existing resources, such as recording instructional videos, online Q&A, Physics experiment based on smartphone, virtual experiments, optical simulation experiments etc. As our lives enter into the Network Information Age, it brings us a lot of convenience. We can use a variety of ways to make up for the regret of not being able to teach in class, so that students can complete experimental courses at home.

C1.8-04 | 10:30 AM - 11:45 AM | Board Game to Facilitate Discussions on Systemic Bias

Presenting Author **|** *Kristine Lui*

There is abundant research showing systemic biases in STEM and academia. Facilitating a discussion around these issues, and ways to mitigate them, can be challenging. In this poster, I present a board game demonstrating how biases in the system disadvantage some people disproportionately, creating an inequitable system. This generates discussions about sources and consequences of these biases (unconscious bias, socioeconomic strata, etc.) Students brainstorm strategies to 'change the system' and with these new structures, the game is replayed to demonstrate decreased inequity.

C1.8-05 | Open Source Textbook: Exploring Physical Phenomena

Presenting Author **|** *Emily van Zee, Oregon State University*
Additional Author **|** *Elizabeth Gire, Oregon State University*

Exploring Physical Phenomena: What happens when light from the Sun shines on the Earth is now available athttps://open.oregonstate.education/physicsforteachers/. We developed this open source textbook in a laboratory-based physics course for prospective elementary and middle school teachers. Explorations mostly involve everyday equipment so portions also are appropriate for use in general science courses, hallway exhibits, and outreach activities. Units include the nature of light phenomena, nature of thermal phenomena, influence of light and thermal phenomena on local weather, influence of light and thermal phenomena on global climate change, and nature of astronomical phenomena such as phases of the moon. Emphasis is upon questioning, predicting, exploring, and discussing what one thinks and why. This open source textbook also emphasizes the integration of science and literacy learning. Each unit ends by making connections to the Next Generation Science Standards. Supplementary materials include equipment lists suitable for both on-campus and remote learning contexts.

C1.8-06 | Physics Teacher Collaboration in Pandemic Times

Presenting Author **|** *Matthew Perkins Coppola, Purdue University Fort Wayne*
Additional Author **|** *Mark Masters, Purdue University Fort Wayne*

The rapid transition to virtual teaching in March 2020 created opportunities for panic and chaos in high school classrooms across the country. Our physics teacher advisory group (TAG) in Northeast Indiana quickly became an important resource for high school and university faculty. In multiple Zoom meetings, participants shared strategies, evaluated digital tools, created wish lists, and vented frustrations. Grant funding was diverted to schools in need of materials for at-home laboratory activities. Two members shared their personal experience and recovery from COVID-19. While a significant resource before the pandemic, the ability of the group to provide community to otherwise isolated physics teachers demonstrated the need to broaden our mission and increase our commitment of university resources for this venture.

C1.8-07 | Delivering Integrated STEM Professional Development in an Online Environment

***Presenting Author* |** *Debbie French, Wake Forest University*
Additional Author | *Matt Peitzman, Pennridge High School*
Additional Author | *Richard French Mark, Purdue University*
Additional Author | *Sean Hauze, San Diego State University*

This talk focuses on how a traditional, face-to-face teacher professional development workshop series on electric guitars, acoustic guitars, CNC/Electric guitar hybrids was rapidly switched to be delivered in an online environment using Canvas. The switch posed a particular problem because of the hands-on nature of the workshops. The workshop series also served as a model for teachers as they were considering how to teach a project-based course online. This talk will highlight a roadmap for PD providers who may be facing similar situations. Workshop outcomes and lessons learned will also be shared.

C1.8-08 | 10:30 AM - 11:45 AM | Physics for a Classical Education Minor

***Presenting Author* |** *Paul Hosmer, Hillsdale College*

How does physics fit into the Classical Education paradigm? What must any student pursuing a minor in Classical Education know about physics? A previously-offered one-credit undergraduate seminar course “Teaching Secondary Physics” has been redesigned to be accepted as an elective in the Classical Education minor program at Hillsdale College, directed toward future physics teachers in a classical school setting. In addition to modules on physics standards and the various components of a standard physics course (lecture, lab, equipment, demos, homework, exams, texts), the course specifically addresses the place and role that physics can and should play in the growing Classical Education movement. Topics of discussion in this component of the course include views of physics and physics education in the Classical School movement, what Classical pedagogy might look like as applied to the physics classroom, and special topics dealing with thinkers from Aristotle to Francis Bacon to C.S. Lewis.

C2.01 |Applying Network Analysis to Physics Education

JANUARY 12, 2021 | **1:30 PM - 2:45 PM**
Sponsor: *Committee on Physics in Pre-High School Education*

C2.1-01 | Network Analysis of the FCI and the FMCE

Presenting Author | Christopher Wheatley, West Virginia University
Additional Author | James Wells, College of the Sequoias
Additional Author | Rachel Henderson, Michigan State University
Additional Author | John Stewart, West Virginia University

Network analytic techniques such as Modified Module Analysis (MMA) and Modified Module Analysis – Partial (MMA-P) are powerful new tools which can identify coherent patterns of student responses to physics conceptual instruments. MMA and MMAP are 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. These techniques were applied to 4000 student responses to the Force Concept Inventory (FCI) and the Force and Motion Conceptual Evaluation (FMCE) both prior to and post instruction. These studies identified a coherent set of non-Newtonian misconceptions in both the FCI and the FMCE. They also revealed communities of isomorphic items, issues with item-blocking, and items not functioning as intended within the instruments.

C2.1-02 | Network analysis of the CSEM with Modified Module Analysis

Presenting Author **|** *Christopher Wheatley,*
Additional Author | James Wells, College of the Sequoias
Additional Author | Rachel Henderson, Michigan State University
Additional Author | John Stewart, West Virginia University

This research applied Modified Module Analysis (MMA) to over 5000 student responses to the Conceptual Survey of Electricity and Magnetism (CSEM). The CSEM was given at two major US land-grant universities in the introductory Electricity and Magnetism courses. MMA is a powerful tool for analyzing large datasets that uses the correlation matrix to form a network, community detection algorithms, and bootstrapping. Many studies have investigated student misconceptions in Newtonian physics by analyzing instruments such as the Force Concept Inventory or the Force and Motion Conceptual Evaluation. These studies showed that students hold non-Newtonian views on classical mechanics even post-instruction. However, much less research has investigated misconceptions in E&M. This study identifies communities of correct and incorrect answers to the CSEM to explore the structure of student misconceptions.

C2.1-03 | Multilevel Network Analysis: A New Dimension for Analyzing Concept Inventories

Presenting Author **|** *James Wells,*
Additional Author | Christopher Wheatley, West Virginia University
Additional Author | John Stewart, West Virginia University

Modified Module Analysis using partial correlations (MMA-P) has been a productive method for studying concept inventories. MMA-P finds patterns in student responses, which can represent common alternative conceptions, test-taking strategies, or structures arising from the construction of the instrument. MMA-P has shown that because of these structures, grading each item independently underestimates students' understanding of the material and that concept inventories written with highly attractive distractors may not detect the full spectrum of students' reasoning. MMA-P can be extended by using multilevel network analysis. With multilevel techniques, populations of students can be disaggregated in the MMA-P analysis. For example, a multilevel network could be constructed with data from different institutions forming different levels in the network. Within each level, MMA-P finds modules of popular responses within an institution. Common responses form edges that link institutional networks ..together, opening a new dimension for MMA-P to find patterns that cross institutional boundaries.

C2.1-04 | Social Positions in Group Exam Networks

Presenting Author **|** *Adrienne Traxler, Wright State University*
Additional Author | Steven Wolf F., East Carolina University

This talk presents a network analysis of group exam data from a two-class introductory physics sequence. In each class, on each of four exams, students took the exam individually and then reworked it with classmates. Students recorded their collaborators before submitting the exam, and these reports are used to build directed networks. The networks are partitioned using positional analysis, which uses similarities in linking behavior to detect blocks of actors in a network. By calculating block structure for each exam and mapping over time, it is possible to see a stabilizing social structure over the two semesters. Some students find a coherent group immediately, while others take longer, but almost all settle into a regular set of collaborators by the second semester. We will discuss this evolving block structure, what it suggests about the social positions available to students in the classes, and how network position connects to exam grades.

C2.1-05 | Examining Response Patterns to Multiple-Response Items Using Module Analysis

Presenting Author **|** *Trevor Smith, Rowan University*
Additional Author | *Philip Eaton, Stockton University*
Additional Author | *Michael Hoang, Rowan University*
Additional Author | *Suzanne White Brahmia, University of Washington*
Additional Author | *Alexis Olsho, University of Washington*

We have developed a multiple-choice test for measuring students' quantitative literacy in the context of physics (Physics Inventory of Quantitative Literacy, PIQL). Items were created based on the framework of conceptual blending in which students' mathematical reasoning and conceptual physics understanding cannot necessarily be separated. As such, we include several multiple-choice/multiple-response (MCMR) items to which students may select as many answer choices as they think are correct. Common factor analysis techniques for identifying groups of items that share common traits are inappropriate because these methods require MCMR items to be scored dichotomously, which destroys the rich information available in students' response pattern. As an alternative, we use Modified Module Analysis (MMA) to identify communities based on networks of correlations between answer choices. We present the results from using MMA to analyze networks of correct responses to PIQL items, networks of incorrect responses, and networks of all responses combined.

Supported by NSF Awards DUE-1832836, DUE-1832880, and DUE-1833050.

C2.02 | B-sides and Bloopers from Famous Physicists PLUS Cartoon Physics

JANUARY 11, 2021 | **1:30 PM - 2:45 PM**
Sponsor: *Committee on History & Philosophy of Physics*
Co-Sponsor: *Committee on Physics in High Schools*

C2.2-02 | The Troublesome Tides

Presenting Author | *Bradley McCoy, Azusa Pacific University*

Before being solved by Newton and Laplace, explanation of the cause of the tides was a long-standing problem. In this talk, we will look at two failed attempts to explain tides: Galileo's "alternately accelerated and retarded motion" published in Discourse on Two World Systems in 1632 and George-Louis Leclerc's hilariously implausible description of tides due to blocking of ocean currents in The System of Natural History, Vol.1 in 1741, over 50 years after Newton.

C2.2-04 | Benjamin Franklin's Most Dangerous Experiments

Presenting Author **|** *James Lincoln, AAPT Films*

Benjamin Franklin was a first-rate physicist. Yet, his experiments and demonstrations almost killed him several times, and once even shocked him completely unconscious. Valiantly carrying on, Franklin was the de facto founder of the science of electricity and even a publishing member of the Royal Society of London. In this talk, allow me to introduce you to Benjamin Franklin the Physicist as I outline his most important and dangerous discoveries, demonstrate them, and explain why the heck he thought that positive charge flowed in conductors.

C2.2-01 | Cartoon Physics in the Classroom

***Presenting Author* |** *Kenric Davies, PTRA, Liberty High School, Frisco TX*

We have all experienced it; watching a movie (cartoon or not) where something happens that is a physical impossibility making all the physicists in the room cringe. Someone walks off a cliff and doesn't fall until the look down (looking at you Wyle E. Coyote) or the path of a launched object looks nothing like a parabola…it can be infuriating. But, instead of raging against the incorrect, why not use it to teach how the world really works? Students are surprisingly good at picking out the incorrect physics when watching cartoons, but they also can fall into traps believing that real life emulates the cartoon world. During this talk, I will detail my experiences using cartoons to teach physics to high school students and pre-service elementary teachers.

C2.2-03 | 01:30 PM - 02:45 PM | Maxwell and the Color Wheel

***Presenting Author* |** *Jill Macko, Eastern Nazarene College*

All physicists know of Maxwell's equations. Many know of Maxwell's statistics. But only a few know of Maxwell's theory of color vision. In this talk I will discuss James Clerk Maxwell's work on color science, including his experiments with the color wheel, his invention of the color triangle and the first ever color photograph.

C2.3-03 | Freedom, Innovation, And Makerspaces; Creating New Campus Realities

***Presenting Author* |** *Brian Kays, The Webb Schools*

The evolution of NGSS standards and the influence this has had at the HS level has created an important inflection point nationally for new innovation and policy about how we can integrate engineering and design, not just in science, but across entire campuses. Four years ago, the creation of the Maker Den at Ramona Convent Secondary School (the first all-girls makerspace in Southern California) allowed for a transformational change in not only how students, but teachers across all disciplines, integrate engineering skills. The goal was to create policies and procedures that allowed for the building of anew community of collaboration between teachers in an innovative shared physical space. This is a story of collaboration, stake holder engagement, empowering community, and then giving up control to let it thrive. The creation of this fertile soil resulted in the Maker Den being featured at the 2019 International Symp. of Academic Makerspace at Yale.

C2.3-01 | Influencing State Politics

Presenting Author **|** *Melissa Grimshield, Tolleson Union High School District*

Being an advocate for physics and STEM education does not need to mean leaving the classroom. In this session, the speaker will share how she became a state-level education advocate, from actions at the state capitol during the 2018 Arizona teacher walkout to working alongside lawmakers to pass a bill that provided $1.2 million in scholarships for STEM and CTE teachers.

Melissa Girmscheid is in her twelfth year of teaching, currently at West Point High School in Avondale, Arizona. In 2018 Melissa was chosen as an AIP/AAPT Master Teacher Policy Fellow, part of a team of Arizona physics educators devoted to saving the profession in Arizona. In addition to this advocacy, Melissa is an AMTA workshop leader, specializing in Computational Modeling in Physics First with Bootstrap, and the current AMTA Vice President. She holds National Board Certification and is a STEP UP Ambassador.

C2.3-02 | Advocating for Policies That Authentically Support University Students

Presenting Author **|** *Kelli Warble, Arizona State University*

The Arizona State University Charter describes ASU as a "public research university, measured not by whom it excludes, but by whom it includes and how they succeed." This motto is both inspirational and aspirational, but often policy decisions are made by those far-removed from the daily experiences of both instructors and students. The result is threatened elimination of programs supportive of this inclusive message in favor of those seemingly contrary to this call to action. This session will share lessons learned by ASU physics instructors as they advocated, both successfully and unsuccessfully, for policies they believed would positively impact the students they serve every day. Examples include the near elimination of the LA program during the COVID-19 crisis and working groups of concerned physics department stakeholders engaged with the APS IDEA (Inclusion, Diversity, and Equity Alliance) network.

C2.3-04 | Teachers Impacting International Educational Policies

Presenting Author **|** *Rebecca Vieyra, Organization of American States*
Additional Author | *Kenesha Foster, Charles E Mills Secondary School*
Additional Author | *Jason Douglas, The Anglican High School*
Additional Author | *Lynn Jorgensen, Gilbert High School*
Additional Author | *Carmen del Pilar Suarez Rodriguez, ITEN Teacher Fellowship Coordinator*

This presentation will feature the stories of multiple physics teachers across the USA, Latin America, and the Caribbean who have participated in the Inter-American Teacher Education Network. Each of these teachers has been recognized for their role as teacher leaders, and they will share how they have worked to impact the policies and practices of their schools and educational systems. These teachers will provide exemplars for how other physics teachers across the hemisphere can become agents of change in diverse ways.

C2.04 | (C2.04) Effective Practices in Educational Technology III

January 11, 2021 **| 1:30 PM - 2:45 PM**

Sponsor: *Committee on Educational Technologies*

C2.4-01 | "5-Star" Student Self-Assessment for Online Homework Solutions in General Physics

***Presenting Author* |** *Jerry Artz, Hamline University*

Most teachers of general physics and other physics courses have been dismayed by the rampant student use of and dependence upon online homework solutions. I have developed a “5-Star Rating,” done by students, to indicate use, or no use, of online solutions in the solving of physics homework problems. A 5-star problem can be achieved if you can work a problem without use of the book, notes, or other people. Or, you can work your way down to a 0-Star problem utterly copying without understanding. The emphasis is on honesty and integrity. If students use an online solution, they must reference it! If someone else helps, give them credit! One’s homework grade is not reduced by star-rating the problem. In fact, a small bit of extra credit is awarded should a student use 5-Star Rating. The 5-Star Rating system and possible correlations between 5-Star Rating and performance will be discussed.

C2.4-02 | A in the Chat: Remote Engagement Inspiration from Streaming Culture

Presenting Author | *Jax Sanders, Marquette University*

Promoting engagement in large synchronous sessions can be challenging, particularly for educators who are not used to working in the online format. Students are reluctant to engage in large-format online groups, leaving online synchronous sessions feeling passive. Community-engaged online performers, or streamers, have developed techniques for promoting interest and engagement from a text-based “chat” of viewers. If our goal is to promote engagement with online synchronous class content, this contemporary entertainment medium offers relevant and timely examples of promoting interactivity in a remote synchronous format. These solutions can range from technological add-ons to active engagement techniques that are adaptable to educational technology and active learning. This paper will present techniques, case studies, and examples of application to a remote introductory physics course.

C2.4-03 | 0Tools to Support On-line Small Group Activities

***Presenting Author* |** *Tamara Snyder, University of Arkansas, Fayetteville*
Additional Author | *Jennifer Palomino, Texas State University at San Marcos*
Additional Author | *Kristin Wedding Crowell, California State University - East Bay*

The Physics and Everyday Thinking Curriculum is built around students talking and working together. In the classroom groups have white boards and the instructor circulates to monitor work and ask questions. In online environments, an instructor can only be present with one group at a time, and an instructor showing up in a breakout room can disrupt the student-student discussions. Providing groups with shared documents, virtual whiteboards and other collaboration tools not only makes their group work more productive, it also provides a way for the instructor to unobtrusively monitor multiple groups simultaneously. In this talk we will present a variety of tools we have used from the Google Suite as well as our experience using Microsoft Teams. This is part of a series of talks stemming from the NextGen PET FOLC project. This work was supported by the National Science Foundation grant NSF DUE-1626496.

C2.4-04 | Teaching Science Content with Jupyter at Scale, Elementary Through University

***Presenting Author* |** *Adam LaMee, Quarknet & Univ. of Central Florida*

Equal access to lucrative careers depends on every student being exposed to coding and science courses are prime territory for this task. Jupyter, Binder, and Colab have been critical tools for making that happen. They're free, used in research, and enable non-CS-fluent instructors to give their students meaningful exposure to introductory programming and data science. I'll share lessons learned from helping school districts embed coding activities into core science curriculum for over 15, 000 middle schoolers annually. I'll also report more recent developments using this strategy in remote physics courses at the 2nd largest US university and in Quarknet's Data Camp for high school teachers.

C2.4-05 | An Accelerated Physics Course Remotely with Sgls And Physical Labs

***Presenting Author* |** *Garnett Cross, Andrews University, AU Physics Enterprises*
Additional Author | *Tiffany Summerscales, Andrews University*
Additional Author | *Michael Bryson, Andrews University*
Additional Author | *Mickey Kutzner, Andrews University*
Additional Author | *Margarita Mattingly, Andrews University*

This summer provided an opportunity to innovate amid the pandemic. Andrews University's Department of Physics developed an entire series of labs that were completed with equipment that was cheap enough to supply to each student. Pre-recorded lectures were combined with remote, concurrent small-group learning assignments and laboratory exercises to reach students in our summer intensive physics course with the largest ever enrollment. A real laboratory experience, while being away from campus combined with easy access to professors increased student engagement.

C2.4-06 | The Use of Recorded Data Labs to Conduct Online Experiments

***Presenting Author* |** *Jack Gilbert, MechNet Inc.*

We have developed a system that allows students to conduct experiments with real world data recorded from an actual test of the equipment. This is not a virtual reality simulation. This is real data recorded during the operation of the experiment in progress. The student uses a National Instruments LabVIEW program to actually control the equipment and view the data in the exact same manner as if the equipment where in their classroom. In many cases the recorded data labs are "Better than Real Life". Since they have continuous access to the software. This also allows students to conduct experiments with equipment that in most cases is to expensive to purchase for the limited amount it would actually be used in the lab. They will have access to a model roller coaster, chassis dynamometer, brake dynamometer, single cylinder combustion engine dynamometer, turbine engine dynamometer and wind tunnel.

C2.05 | Highlights of Astronotes

January 11, 2021 **| 1:30 PM - 2:45 PM**

Sponsor: *Committee on Space Science and Astronomy*

C2.5-01 | Kepler's Cosmic Harmony, Orbital Eccentricities & Musical Intervals

***Presenting Author* |** *Michael LoPresto, University of Michigan*

It is well known that in his pursuit of "Cosmic Harmony," Johannes Kepler believed that the planets were singing musical scales as the speeds of their orbits varied. In no small part because of his Laws of Planetary motion, we now know that these varying speeds are due to orbital eccentricities. It turns out that the eccentricity of the orbit of each planet known in

Kepler's time can be used to calculate the numerical frequency-ratio for the musical interval spanned by the scale Kepler believed each planet was singing. This talk will provide some background onKepler's ideas about "Cosmic Harmony," the mathematics of musical intervals and scales and describe the derivation of the expression used and report the results.

C2.5-02 | Backyard Astronomy During A Pandemic

Presenting Author **|** *Chris Sirola, University of Southern Mississippi - Hattiesburg, MS*

Teaching astronomy remotely is a challenge. While many activities and programs are available on-line, students are not guaranteed to have the needed Internet access or bandwidth. Active learning also becomes a problem if students cannot interact with fellow students or instructors in person. A modern version of an ancient instrument called the astrolabe can be used for several backyard projects, from analzying the orbit of the Moon to the apparent retrograde motion of the planets. We show how to construct and use an astrolabe and discuss potential lessons.

C2.5-05 | Bringing Machine Learning to Introductory Astronomy Labs

Presenting Author **|** *Donald Smith, Guilford College*

Machine Learning (and its cousin Deep Learning) is rapidly making inroads into almost every academic and commercial endeavor. Astronomy is no exception. Researchers are developing tools to classify stars, identify quasars, correct adaptive optics for atmospheric noise, and many other applications. Learning these tools is becoming an essential facet of graduate study. However, I have not yet found anyone incorporating them into the undergraduate introductory astronomy lab. I recently taught a three-week general education course on machine learning for non-scientists, and I am adapting the activities from that course to an introductory laboratory sequence in an upcoming course on Galaxies and Cosmology. I will report on the success of my first course and how I plan to teach beginners to use Python tools in the Google Colaboratory on publicly available Astronomical data sets to deepen their understanding of the universe.

C2.5-04 | 01:30 PM - 02:45 PM | AstroNotes: Where Astronomy is a Verb

Presenting Author **|** *Timothy Slater, University of Wyoming*

As one of the oldest sciences taught, astronomy penetrates to all aspects of society: science, culture, religion, timekeeping, and exploration. And the topic coverage in the domain of astronomy is grand, the entire universe in fact. In this sense, there could be a whole lot to memorize as a novice astronomy student. In fact, there is so much material one could memorize, that an effective astronomy class should probably have a highly constrained amount of memorization at all because, at its very essence, astronomy is not something you memorize, astronomy is something you do. In short astronomy is a verb. The folk wisdom of how to teach astronomy as a culture-encompassing science that is action oriented has been developed over many generations, but by and large that wisdom gets lost. AstroNotes is decades long archive of the collected wisdom for teaching astronomy as something students do rather than memorize.

C2.06 | PER: Student and Instructor Support & Professional Development, Program and Institutional Change

January 11, 2021 **| 1:30 PM - 2:45 PM**

C2.6-01 | 01:30 PM - 02:45 PM | Scientists Views on Ethics in their Research

Presenting Author | *Tyler Garcia, Kansas State University*
Additional Author | James Laverty T, Kansas State University

Scientific researchers across all disciplines are routinely faced with ethical dilemmas in their work. To help strengthen their ethical reasoning skills, they are encouraged to take online training programs (e.g. CITI program, the Office of Research Integrity's "The Lab"). We argue that these programs will be more effective if they are better aligned with how working scientists think about these dilemmas. The main goal of this study is to investigate how research professors think about ethical issues in their own work. In this study, we interviewed fifteen scientists from several disciplines asking how they conduct their research and then presented several different case studies involving ethical dilemmas. We analyze these interviews by focusing on the goals and values the scientists express in their ethical reasoning about these cases. This work will inform future development of ethics education programs.

C2.6-02 | Student Experiences with Emergency Remote Teaching in Fall 2020

Presenting Author | *Michael Vignal, University of Colorado Boulder*
Additional Author | Bethany Wilcox, University of Colorado Boulder

In the Spring of 2020, in response to the COVID-19 pandemic, many colleges and universities transitioned to a new modality of teaching that we refer to as `emergency remote teaching' (ERT). As ERT is likely to continue through the Spring of 2021, we seek to learn about the student experience with ERT in order to better inform ERT instruction. Building from student responses to a survey administered in the Spring of 2020, in this talk we discuss the development of and student responses to a new ERT survey administered in the Fall of 2020 and sent to hundreds of physics departments across the US. We asked students to share their experiences with lectures, labs, exams, and other elements ERT in their physics courses to hear from students about what worked well (and what didn't), and what got better since ERT in the Spring (and what got worse).

C2.6-03 | Cultures of Assessment and Change in US Physics Departments

Presenting Author | *Sara Frederick, University of Maryland*
Additional Author | Rob Dalka, University of Maryland
Additional Author | Chandra Turpen, University of Maryland
Additional Author | Joel Corbo, University of Colorado Boulder
Additional Author | Stephanie Chasteen, Chasteen Educational Consulting

The APS Effective Practices for Physics Programs (EP3) project team surveyed department chairs nationwide to assess the status of physics-degree-granting departments (modeled in part on the DELTA survey design pioneered by Ngai et al 2020). These results inform the development of the EP3 Guide on effective departmental change, assessment practices, and program review. The respondents (N=310) reported perceiving the assessment of student learning and departmental program outcomes as currently largely driven by compliance and not leading to valuable change. The chairs also indicated that their vision for an ideal department was significantly misaligned with their current modes of operation. The change strategies with the most potential for improvement were 1) engaging multiple stakeholders and 2) using data effectively. These gaps highlight opportunities for growth where leaders' motivation to align their department practices with their ideal values may be channeled toward supporting cultures of assessment and effective change.

C2.6-04 | Comparing Gtas’ Use of Teaching Strategies in Recitations and Labs

Presenting Author | *Constance Doty, University of Central Florida, Department of Physics*
Additional Author | Ashley Geraets A, University of Central Florida, Department of Chemistry
Additional Author | Tong Wan, University of Central Florida, Department of Physics
Additional Author | Erin Saitta K H, University of Central Florida, Department of Chemistry
Additional Author | Jacquelyn Chini J, University of Central Florida, Department of Physics

To improve the teaching practices used by STEM graduate teaching assistants (GTAs) who lead student-centered lab and recitation sections, STEM departments need to improve the training GTAs receive. In our study, seven physics “mini-studio” (combined recitation and lab) GTAs participated in three to four practice teaching sessions with a mixed-reality classroom across two semesters. During each practice session, GTAs were prompted to practice implementing student-centered teaching strategies into their discussion about a lab or recitation (tutorial) activity with a virtual class of five avatar-students. To assess the effectiveness of the simulator training, we also observed GTAs teaching in their real classroom two to three times each semester. In this talk, we investigate which teaching strategies GTAs implemented in two different classroom settings (recitation and lab). We also discuss the frequency of each teaching strategy used and provide examples to inform GTA professional development.

C2.6-05 | Prevalence and Nature of Threats Facing U.S. Physics Departments

Presenting Author | *Robert Dalka, University of Maryland, College Park*
Additional Author | Sara Frederick, University of Maryland, College Park
Additional Author | Chandra Turpen, University of Maryland, College Park
Additional Author | Joel Corbo C, University of Colorado, Boulder
Additional Author | Stephanie Chasteen V, Chasteen Educational Consulting

The APS Effective Practices for Physics Programs (EP3) project team surveyed department chairs nationwide to assess the status of physics-degree-granting departments (modeled in part on the DELTA survey design pioneered by Ngai et al 2020). As part of this survey, department chairs were asked to reflect on threats, unrelated to the Covid-19 pandemic, to the continuity of their programs. These threats included financial strain, reductions in personnel, and deprioritization by administration. Of the survey respondents (N = 310), 45.2% reported experiencing a moderate or severe threat, which is substantial and concerning. A majority of departments facing threats were unlikely to consult outside resources when addressing the threatened actions. Resources developed by professional societies paired with collective responses from the larger physics community may be needed to support these departments in addressing threats.

C2.6-05 | Opening Engineering Pathways: A University and High School Physics Partnership

Presenting Author **|** *Maggie Mahmood, University of Illinois at Urbana-Champaign*

Access to high-quality, advanced physics instruction in high school can open pathways for students to attain university STEM degrees by preparing them for gate-keeping undergraduate physics courses. However, access to advanced high school physics instruction is not universally available. In response, the Physics Education Research Group at University of Illinois a tUrbana-Champaign created the partnership program Illinois Physics and Secondary Schools (IPaSS), bringing together Illinois high school physics teachers to participate in intensive PD experiences structured around award-winning, university-level instructional materials (such as the iOLab wireless lab system, and web-based, "flipped" platform, smartPhysics). Within the framework of a community of practice, teachers adapt, adopt, and integrate high-quality, university-aligned physics instruction into their classrooms, with the goal of opening more equitable, clear and viable pathways for students into engineering. This talk provides an overview of the partnership program and presents preliminary findings from the first intensive summer teacher PD session.

C2.07 | Physics Education: International Perspectives

January 11, 2021 **| 1:30 PM - 2:45 PM**

Sponsor: *Committee on International Physics Education*

C2.7-01 | 01:30 PM - 02:45 PM | My Journey as a Physics Educator in US

Presenting Author **|** *Mayuri Gilhooly, Rockhurst University*

Teaching is rewarding but lot of hard work for new teachers. It makes it more difficult for immigrant teachers who speak English as a second language. I will address different teaching practices in Sri Lanka in comparison to the US. Physics is a natural science where there are many real-world examples that one can bring into the classroom when teaching a certain Physics concept. However, this can be challenging if you are a person who didn't grow up in the US. In my personal story, I will address the challenges I have faced and also my successes, how I was able to incorporate my traditional background and language into teaching and relationship building which is often difficult for some non-American teachers. I will also address actions I have taken to improve my teaching and to adapt to US styles of teaching and learning.

C2.7-02 | Bringing Inquiry-Based Learning in Antioquia Colombia through Teacher Training

Presenting Author **|** *Diana López Tavares, PhET Interactive Simulations*
Additional Author | *Laura Arboleda Hernández Catalina, Institución Universitaria Digital de Antioquia*
Additional Author | *José Ramírez Arboleda Julián, Institución Universitaria Digital de Antioquia*
Additional Author | *Jorge Gómez López Alberto, Institución Universitaria Digital de Antioquia*

Inquiry-Based Learning is a trend in science classrooms. However, bringing Inquiry-Based Learning to Colombian classrooms has been a slow process. Most of the professional development programs for teachers in Colombia are large, short-duration workshops with very ambitious goals and with a focus on tools (such as Moodle, sensors in smartphones, etc.). Only a few workshops are about methodologies, and most of these are focused on theory with reduced context. Over the past few years, we have designed and delivered teacher workshops in several Latin-American countries, as well as the United States, to support teachers to integrate Inquiry-Based Learning. This presentation will summarize insights from these experiences and discuss the design of a new teacher professional development program to support teachers in Antioquia, Colombia in the adoption and implementation of Inquiry-Based Learning methodologies in K12 science classrooms. The activities designed include the use of free PhET simulations and low-cost experiments.

C2.7-03 | 01:30 PM - 02:45 PM | The Intersection of Physics Identity and Asian Identity

Presenting Author **|** *Linda Zhang,*
Additional Author **|** *Kerstin Nordstrom, Mount Holyoke College*

Asian/Asian American physics students lack ample representation in physics identity studies and in the broader STEM sociological literature. This may be due to their perceived “overrepresentation,” the “model minority” myth, or their treatment as monolithic. These misconceptions obscure the diversity amongst Asian students. How do these students understand and form their physics identity? Through in-person interviews, we have gathered data on the experiences of self-identifying Asian/Asian American undergraduate physics majors. For our analysis, we draw from previous physics identity research and use the Critical Physics Identity framework developed in a recent paper on Black physicists’ identities.1 We present results from the Ideational Resource code and emergent codes generated from the data, such as Transnational Context and Asianization.

S. Hyater-Adams, C. Fracchiolla, N. Finkelstein, and K. Hinko, Critical look at physics identity: An operationalized framework for examining race and physics identity, Phys. Rev. Phys. Educ. Res. 14, 010132 (2018)

C2.7-04 | Examine High-School Physics Education Driven by High Stakes Testing

Presenting Author **|** *Jianlan Wang, Texas Tech University*

Standards based reform has been one prominent feature of the current educational landscape in the US since 1980s. High-stakes testing (HST) is key to the administration of standards as it holds schools accountable to meet the standards, changes the behavior of teacher and students in desirable ways, and monitors student achievement required by standards. High-school physics education (HSPE) in China is driven by the HST of college entrance examination, also known as Gaokao. I will compare HSPE between the US and China in reference to sample questions from Gaokao in China and their counterparts in the US. I will illustrate how HSPE in the two systems prepare students for the tests. Finally, I will analyze the longitudinal impacts of the two systems on students’ physics learning in college. I intend to give an insight into what is taught and how it is taught about physics in an HST-oriented context.

C2.7-05 | Teaching Physics on Three Continents

Presenting Author **|** *Igor Proleiko, Dipont Education*

Drawing on personal experience of teaching Physics in the former Soviet Union, in the inner city St. Louis, and in AP Centers in China comparison of method, environments and students are discussed. Challenges and advantages of different environments are compared.

C2.08 | Promoting Retention and Making Physics More Accessible

January 11, 2021 **| 1:30 PM - 2:45 PM**

C2.8-01 | Undergraduate Suborbital Research: Increasing Student Engagement Through Community College Partnerships

***Presenting Author* |** *Jennifer Jones, Arapahoe Community College*
Presenting Author **|** *Barbra Sobhani, Red Rocks Community College*

Undergraduate research is a high-impact practice, shown to engage STEM students and increase retention, especially in underrepresented populations. Providing educational access to a diverse student population, community colleges are a vital part of the STEM pipeline, so it is critical to develop research skills as early as possible in their academic career. Colorado Space Grant Consortium has allowed our students and faculty access to excellent research opportunities at an affordable price, including payloads on high altitude balloons and sounding rockets. However, the cost of doing research on suborbital rockets, even through COSGC, can be prohibitive. In order to facilitate a student designed and built payload flown on a sounding rocket, Red Rocks Community College and Arapahoe Community College partner, combining resources both financial and advisory. The project is extra-curricular, allowing a wide range of student backgrounds and interests to participate and acquire a wide array of engineering and scientific skills.

C2.8-02 | Providing a Path to Success in Introductory Physics

***Presenting Author* |** *Beth Parks, Colgate University*

We all know what student behaviors lead to success in the long run: work steadily, review homework solutions and in-class problems, organize equations and concepts, work practice problems. The challenge is that some of our students enter with particularly weak backgrounds in science and mathematics. If these strategies don't work quickly enough to allow students to succeed in their introductory course, they drop out and switch majors. The solution: give students an alternate path, a “grade guarantee.” Students who complete all these successful behaviors are guaranteed a grade of C on each test, and therefore have a clear path to success in the course, and exit the course well prepared for the next course. This talk will describe how this grade guarantee can be put into effect without creating an undue burden on students or faculty.

C2.8-03 | Training Physics Students to Diffuse Racial Microaggressions

***Presenting Author* |** *Erin De Pree, St. Mary's College of Maryland*

Building an inclusive culture takes time and training. This is a curriculum using the strategies proposed in Sue et al's 2019 paper "Disarming Racial Microaggressions" (American Psychologist 74, 1, 128-142). The goal of the training is to practice responses to microagressions that are likely to occur in physics and future job settings. The goal is to give students options when they encounter a microaggression occurring in the future. In this presentation, we explain the pre-class set up, trigger warnings, in class discussions, and post-class practice and reflections. It is particularly important to remove the expectation that students of color are somehow responsible for educating the rest of the class, this is an unfair burden that will take away from their study of physics.

C2.09 | Recent Developments and Perspectives in Research on Student Reasoning

January 11, 2021 | **1:30 PM - 2:45 PM**

C2.9-01 | 01:30 PM - 02:45 PM | Examining and Supporting Student Reasoning using Novel Methodologies*

Presenting Author **|** *MacKenzie Stetzer, University of Maine*

For over 30 years, research-based materials developed by the physics education research community have helped transform introductory physics instruction. Many of these materials focus on the development of student conceptual understanding and place considerable emphasis on qualitative inferential reasoning. An emerging body of research, however, suggests that poor student performance on certain physics tasks – even after research-based instruction – may stem more from the nature of student reasoning itself than from specific conceptual difficulties. As part of a larger, multi-institutional effort to examine and support student reasoning in physics, we have been developing methodologies to probe student reasoning and designing and testing interventions to better support productive reasoning.New research tasks, informed by dual-process theories of reasoning, and associated results will be discussed.

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

C2.9-02 | Finding Potential Pathways between Expert and Student Physics Quantitative Reasoning

Presenting Author **|** *Suzanne White Brahmia, University of Washington*
Additional Author | Trevor Smith I, Rowan University
Additional Author | Philip Eaton, Stockton University
Additional Author | Charlotte Zimmerman, University of Washington
Additional Author | Alexis Olsho, University of Washington

Quantitative reasoning in introductory physics is characterized by using simple mathematics in creative and novel ways. Physics Quantitative Literacy (PQL) is characterized by the blending of conceptual and procedural mathematics to generate and apply models relating physics quantities to each other. As part of developing a PQL assessment instrument, the Physics Inventory of Quantitative Literacy (PIQL), we characterized expert reasoning in three domains – proportional reasoning, covariational reasoning and reasoning with sign and signed quantities. Accurately characterizing student reasoning can help guide instructional interventions designed to help students develop more expert-like reasoning. In this talk, I will share ongoing quantitative analyses of student PIQL responses, and related qualitative studies. I will report on reasoning clusters revealed through module analysis, and hierarchical structure using item tree analysis. I will also share results that isolate emergent student resources associated with the three domains of expert PQL in introductory physics.

C2.9-03 | Causal Diagrams to Model Student Difficulties and Productive Thinking

***Presenting Author** | Eric Kuo, University of Illinois at Urbana-Champaign*

Pearl (2000) described a formal methodology for characterizing and investigating cause-effect relationships, which included a formal diagrammatic representation for causal systems. This talk describes initial efforts to use these causal diagrams for modeling qualitative reasoning in introductory physics. Using causal diagrams to characterize students' difficulties in physics, we have found a common causal structure that describes one class of qualitative reasoning error seen across several problem contexts. Causal diagrams also provide a new lens for understanding how students' incorrect reasoning may contain productive resources for learning physics. These initial findings suggest that causal diagrams may be a useful lens for understanding existing findings in PER and guiding future investigations.

C2.9-04 | Dual Process Model of Reasoning: Navigating a Terrain

***Presenting Author** | Andrew Heckler, Ohio State University*

Dual process theories model reasoning and decision making as comprised of both implicit and explicit processes. In these models, decisions can are made via explicit and deliberate thinking with potentially dominant influences from implicit and automatic "thinking", such as strong tendencies for people to reply quickly, use the most available information, and make unwitting assumptions and observations aligned with beliefs and experience. While these implicit influences of human thinking may optimize every-day living and survival, they can also make normative scientific reasoning and understanding more difficult. I show some physics education-relevant examples based on students inferences from tables of data as well as examples from physics conceptual questions. To better conceptualize this process, I introduce a useful analogy to navigating a terrain. The question then becomes, how do we negotiate or change these natural and inevitable "cognitive contours" to help students more effectively learn science and reason scientifically?

C2.10 | Climate Change Solutions: There is HOPE!

January 11, 2021 **| 1:30 PM - 2:45 PM**

Sponsor: *Committee on Science Education for the Public*

C2.10-03 | 01:30 PM - 02:45 PM | Cleaning Up Carbon

***Presenting Author** | Klaus Lackner, Arizona State University*

The world's energy infrastructure creates a huge, unmanaged CO_2 waste stream. Fossil carbon dumping is putting us onto an overshoot trajectory relative to the 1.5°C target set in Paris. Carbon must be drawn down at a staggering scale. Picking up carbon litter implies collecting and storing more carbon than was emitted during the 20thcentury. Storage technologies are unpopular. However, Iceland shows how to form mineral carbonates from CO_2 and basalt deep underground. Collecting carbon poses new challenges. Biomass capture is unlikely to scale. Direct air capture is scalable, but untested and too expensive. Once affordable, it will likely play an important role in climate stabilization. In addition, air capture will support a circular carbon economy. Solar energy, water and carbon dioxide taken from the air will be the ingredients for synthetic fuels for airplanes, ships and trucks. Then there will be no more need for fossil fuels.

C2.10-01 | Direct Air Capture and Achieving Net Zero Emissions
Presenting Author **|** *Steve Oldham, Carbon Engineering*

Steve Oldham is CEO of Carbon Engineering Ltd., a Canadian-based clean energy company. Carbon Engineering is focused on the deployment of Direct Air Capture technology that captures carbon dioxide out of the atmosphere at large scale, so it can be stored permanently underground or turned into clean transportation fuels. As more and more government and corporate leaders around the world are committing to net zero emissions, attention now turns to the cost, feasibility and societal impact of different solutions. Steve will discuss how Direct Air Capture technology is a feasible, available and affordable solution for removing carbon dioxide from the air at large scale; the opportunities it brings for the economy and how it provides the key missing ingredient in net zero plans.

C2.10-02 | The Climate Change Equation Must Contain A Nuclear Energy Term
Presenting Author **|** *Nathan Wahlgren, NuScale Power, LLC*

Electricity production is one of the top contributors to global carbon dioxide emissions. In 2019 almost two thirds of the world’s electricity was produced by fossil fuels; over half of that was produced by coal alone. As the rate of climate warming increases, it is essential that renewable and low-carbon generation be expanded, both to add new generation capacity and replace fossil fuel plants. For over 50 years the world’s nuclear power plants have produced reliable electricity, and nuclear is the best option for replacing base-load fossil fuel sources like coal, oil, and gas with a tiny fraction of the carbon emissions. NuScale Power, LLC, an Oregon-based startup, has developed a small modular reactor that combines that nuclear operating experience with an existing supply chain to provide evolutionary advances in efficiency and safety.

D1.01 | Best Practices in Educational Technology Including PICUP and other cool Computational Stuff!
January 12, 2021 **| 11:30 AM - 12:45 PM**
Sponsor: *Committee on Educational Technologies*

D1.1-01 | Parallel Parking an Aircraft Carrier in Space
Presenting Author **|** *Katie Ansell, University of Illinois at Urbana-Champaign*

For over 20 years, PER at Illinois has largely focused on leveraging technology and organizational structures to support research-based instruction in our large-enrollment introductory courses. In the past, we have referred to this process as 'parallel parking an aircraft carrier.' In response to the Covid-19 pandemic all components of the introductory courses were shifted to an online format. Many of our existing structures to teach physics at scale were transferable to an online setting. Yet, with the loss of physical proximity a new social dimension was added to the 'parallel parking' problem: How do we deliberately support engagement, collaboration, and community in our virtual classrooms? This talk describes our journey to incorporate this social dimension into our instruction in the Fall 2020 semester, highlighting the interplay between pedagogy and the affordances and constraints of online educational technologies, and sharing challenges and successes faced along the way.

D1.1-02 |Analysis of the PICUP Collection: Strengths and Areas for Development

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

The PICUP Collection of Exercise Sets (https://www.compadre.org/PICUP/exercises/) contains over 60 peer-reviewed computation-infused activities for use in various physics courses from high school through graduate study. Each Exercise Set includes an instructor guide, student-facing exercises, and sample implementations for one or more programming platforms. I present an analysis of this collection based on Exercise Set traits such as course context, assignment topic, computational methods employed, course level, programming platforms, word count, and expected completion time. This analysis will highlight the strengths of the PICUP Collection (such as topics and programming platforms that are well represented) and where there is ample room for development (such as topics not yet covered and programming platforms currently underutilized).

D1.1-03 | Supporting Students with Technology During the COVID-19 Pandemic

Presenting Author **|** *A. Gavrin, IUPUI*

For many years, I and my colleagues have used a variety of online tools in support of teaching large enrollment, introductory courses at an urban, public university. With the onset of COVID-19, the roles of these tools have changed dramatically. In addition to the LMS, we have used personal response systems, an online discussion forum, an online homework system, computational methods in Excel, and online simulations for years. We continue to use all of these and have added zoom and video recording of lectures to the mix. In this talk, I will focus on the differences between the present situation and the pre-pandemic world. How has our use of technology and our students' responses to it changed? What can we learn about the value of technology and best practices for its use by observing these changes?

D1.1-04 | Design, Construction and Use of Instructional Videos on using Maple™

Presenting Author **|** *Scot Gould*

In our physics discipline's continual effort to integrate computational problem solving into all levels of our curriculum, videos and accompanying documents were created to help new users learn the computer algebraic and numeric system Maple(tm). Undergraduates are expected to solve computationally based problems each week in their courses. Based upon recommendations from research in the field of educational, each video possesses the following attributes:* a length of twelve minutes or less, * the inclusion of intentional pauses, *a limit of three major concepts, *minimal amount of syntax and functions, *integration of practice/ example physics problems, *a section on troubleshooting, This talk will cover the challenges and successes of 1) designing and generating the videos, 2) the implementation of the desired attributes into each video, and 3) the assessment by new users in introductory and upper division undergraduate physics courses.

D1.05 | Lab Activities in Introductory Electricity and Magnetism

Presenting Author **|** *Marlann Patterson*

""Lab Activities in Introductory Electricity and Magnetism" Moving online has upended all of our courses and may continue to impact us in future semesters. The move to online instruction has necessitated changes in the lab activities for introductory physics. I will discuss how we use lab kits, lab reports, and lab group member assignments in the online environment, including samples of lab instructions and anonymized samples of student submissions."

DI.06 | Physics of Photography and Music in Physics Education

Presenting Author **|** *Walter Freeman, Syracuse University*

STEAM education is sometimes portrayed as something one should do for culture's sake -- that there is a cultural benefit in bridging the perceived divide between the arts and science. Perhaps so! But once that bridge is built, we stand to gain a great deal from walking over it. I have incorporated the study of phenomena from music and photography into both introductory and advanced physics classes as concrete phenomena to help students understand the abstract principles at work. In particular, the acoustics of musical instruments provides an accessible, rich set of phenomena that are very useful in teaching students general principles of normal modes. And, of course, understanding the physics of guitars or cameras can be a great help to musicians and photographers in their craft! I will discuss examples of this from my own experience as a singer and photographer.

D1.02 | Building a STEM-Wide Culture of Change

January 12, 2021 **| 11:30 AM - 12:45 PM**

Sponsor: *Committee on Physics in Two-Year Colleges*

Co-Sponsor: *Committee on Physics in Undergraduate Education*

D1.2-01 | How Non-Science Majors Can Change Science Culture of Post-Secondary Institutions

Presenting Author **|** *Zachary Kovach, Estrella Mountain Community College*

Scientific literacy is now an important topic for the global society dealing with issues such as pandemics, climate change, etc. At most post-secondary institutions non-science majors outnumber declared science majors. However, it is argued that non-science major students and classes may be more important to the scientific culture of a given institution than declared science majors. So how do we nurture scientific literacy in all students? The focus of the Physical Science department (Physics, Chemistry, Geology) at EMCC is a student-centered inquiry-based approach where students gain the skills necessary to be successful in their chosen fields. The geology courses are typically 95% non-STEM majors. Geology classes made science content accessible to non-science majors and the skills associated with scientific investigation can be applied to any chosen career path. The skills I want my student to gain or grow include, critical thinking, problem solving, group dynamics, public speaking, and scientific literacy.

Zachary has been a science educator for 8 years at both secondary and post-secondary institutions, having taught Physics and Geology. He is the current sole Geology faculty member at Estrella Mountain Community College (EMCC) in Avondale, AZ. At EMCC, Zachary has expanded the Geology program by increasing student enrollment, diversifying class offerings, adding multiple teaching adjuncts, rewriting the entire geology curriculum, all while increasing rigor and student engagement in the Geology classes. He utilizes student-centered inquiry-based teaching techniques in an active learning environment by developing skills-focused curriculum. Zachary is also a STEM Modeling instructor for the American Modeling Teachers Association (AMTA).

D1.2-02 | Integration of Calculus and Physics at Community College Level

Presenting Author **|** *Becky Baranowski, Estrella Mountain Community College*

This interactive session will provide information as to how many mathematics faculties have collaborated with physics and chemistry faculty. Presenter(s) will discuss what groundwork needed to be done, challenges, successes, and key things that need to be in place to be successful.

Becky has been teaching mathematics for 21 years and has worked collaboratively with physics and chemistry faculty to bring a seamless student experience across disciplines. For over 7 years, she has taught in a fully integrated learning community for first and second-semester calculus with first and second-semester university physics. She is finishing up her dissertation which pertains to the development and use of a Calculus Concept Inventory.

D1.2-03 | Active Learning in Chemistry at the Community College Level

Presenting Author **|** *Russ Shaffer, Estrella Mountain Community College*
Additional Author | Allen Reyes, Esterlla Mountain Community College

The teaching of chemistry at Estrella Mountain CC is unique in the Maricopa County CC district. We use the modeling method with our students and do many hands-on activities and focus on student engagement and active learning, not the traditional passive lecture method. We have had great success in this pedagogy for the last 10 years and seen our students own their learning and have a better foundation of knowledge for future chemistry courses and other STEM courses. This session will discuss our successes (and failures) in implementing this research-based method of teaching.

Russ Shaffer has been a science teacher since 1985, with 30 years at the high school level in Phoenix, AZ and 5 years at Estrella Mountain CC in Avondale, AZ. His main teaching subject has been chemistry. He has trained many teachers in the modeling method of science teaching at his old HS district and also through Modeling Workshops at ASU. Allen Reyes has been a chemistry teacher for the past 10 years with experience teaching at Arizona State University and Estrella Mountain Community College. He has taken modeling workshops through the American Modeling Teachers Association and is currently applying the modeling methods of science teaching in all his courses.

D1.2-04 | Creativity and Empirical Evidence: A STEAM Approach Towards Scientific Inquiry

Presenting Author **|** *Verena Spatz, TU Darmstadt*
Additional Author **|** *Matthias Ungermann, TU Darmstadt*

Knowledge about scientific inquiry and the Nature of Science (NOS) is deemed an important part of students' education in the USA as well as in Europe and China (OECD, 2016). We have conducted a field study to explore the development of lower high school students' views about NOS during one school year in the region of Hesse, Germany. We found that often students do not achieve an adequate perception of how creativity and empirical evidence are entwined in scientific inquiry. This is hardly surprising, as preservice teachers already feel ill-prepared to convey scientific inquiry in the classroom. Therefore, we have taken first steps towards implementing a NOS module in the newly created "networking area", a highly innovative enrichment of the teacher training program at TU Darmstadt allowing for STEAM approaches. The talk will give an insight into our research findings, describe initial experiences with the NOS module and "networking area".

D1.2-05 | Making Creativity Teachable: What the "A" in STEAM Really Stands For

Presenting Author **|** *Andre Bresges, University of Cologne*

Science is supposed to create solutions to the problems our world is facing, and we do a lot to foster scientific knowledge without students towards this end. But how might we teach to be "creative" and put solutions together using the building blocks of Math, Science, Technology and Engineering? Internationally, there is a growing movement to re-focus on the idea of theSTEAM Curriculum that is driven from the Maker Movement, the Ardiuno Community and educators of the Asia-Pacific area that understands the "A" for "Arts" as a mission to design and create artificats with the needs of human beings at the center. We demonstrate creativity methods such as Design Thinking, Human-Centric Design and Lean Start-up and how they can be integrated with inquiry learning in classrooms. We will compare STEAM teaching to ISLE and 5E teaching methods and compare the differences from the perspective of students.

D1.03 | Effective Practices in Educational Technology IV

January 12, 2021 **| 11:30 AM - 12:45 PM**
Sponsor: *Committee on Educational Technologies*

D1.3-01 | Flipped Virtual Lectures on a Urban Campus

Presenting Author **|** *Paulo Acioli, Northeastern Illinois University*

In spring 2020, campuses across the world had to adpat its teaching practices due to the COVID-19 pandemic. Northeastern Illinois University (NEIU) decided to switch all teaching to remote or online teaching with very little notice. During the summer of 2020 NEIU decided that most of the courses would continue this practice, with a few exceptions. Having the summer to prepare, I decided to teach Mechanics I and Modern Physics I using a flipped classroom approach. Lectures are recorded ahead of time using Zoom and the built-in whiteboard for problem solving. Before the lecture a Just-in-Time Warm Up quiz is administered and the results are used fo rthe initial discussion in the scheduled virtual lecture. After the discussion, students move into Zoom breakout rooms for group work on problem solving and conceptual discussions. I will present the successes and challenges of this approach on an Urban campus.

D1.3-02 | Reengineering General Physics Lab for At-Home Instruction

***Presenting Author* |** *Shannon Clardy, Henderson State University*
Presenting Author | Dever Norman, Henderson State University

Due to the COVID-19 pandemic, the spring 2020 semester was interrupted for many institutions, forcing classes to move online. While many professors cobbled together resources to complete the spring semester, the summer allowed time to develop inexpensive resources to better serve our physics courses, incorporating hands-on activities to increase student engagement and understanding of the material while distance-learning. We have created ten introductory physics lab activities for General Physics I and eight introductory physics lab activities for General Physics II to be performed by students at home in place of the traditional laboratory experience, using simple, inexpensive lab kits and free or inexpensive software and smart phone apps. These lab activities were implemented at Henderson State University during the summer and fall 2020 semesters and could also be adapted for use in high school classrooms.

D1.3-03 | Immediacy by Design: Light Boarding, Streaming, and Recording Engaging Assets

***Presenting Author* |** *W. Blake Laing, Southern Adventist University*

A full-featured AV setup for a lightboard lecture capture system is presented that adds new features and at a dramatically-lower cost (using a Raspberry Pi, an HDMI switcher, and a Stream Deck macro keyboard). A teacher can, for instance, annotate transparent Power Point slides. Similar techniques can be adapted to capture screencasts that are more engaging without the need for post-production work.

D1.3-04 | 3d Physics Apps

***Presenting Author* |** *Marianne Breinig, The University of Tennessee*

Physics models matter and its interactions in a world with three spatial dimensions. It helps our understanding if we can visualize the predictions of a model. This is particular important for introductory physics courses. For some system three-dimensional visual representations can give us a better understanding of the behavior of the system than two-dimensional representations. We are developing 3D interactive animations that run in any modern browser. No special plug-ins are needed. (http://labman.phys.utk.edu/3D%20Physics/) In particular, we are developing tools for optics laboratories. Students are be able to move components on an optical breadboard, align the components, trace a He-Ne laser beam through the system and make measurement. (http://labman.phys.utk.edu/3D%20Physics/optics.html) These tools already form the basis for several online introductory physics laboratories.

D1.3-05 | 11:30 AM - 12:45 PM | Using Desmos for Interactive Visualizations of Physics

Presenting Author **|** *Roberto Salgado, Minnesota State University Moorhead*

Desmos is a surprisingly powerful web-based graphing calculator. I present a quick sample of my Desmos visualizations that I created for my introductory and intermediate physics courses. The URLs to these visualizations will be made available. One nice feature of Desmos is that the end user can look inside to see how things were done. I begin with the visualization of functions (from kinematics, traveling waves, and electric potentials), with parameters controlled by sliders. I then show 2D-visualizations of equipotentials and of wave-interference using implicit functions in Desmos. (Details of the wave-interference visualization will be described in a related poster.) I next briefly describe some geometric visualizations of spacetime diagrams and differential forms (dual vectors) that I use to teach relativity. I conclude with a visualization of the Dirac Delta Function as a sequence of definite-integrals in Desmos [following the presentation in Griffiths' Introduction to Electrodynamics].

D1.3-06 | The Integration of Computational Modeling into A Physics First Curriculum

Presenting Author **|** *John Baunach, Doane Academy*

Having the opportunity to learn computer science is something every high school student should have; however, according to the 2020 State of Computer Science Education: Illuminating Disparities report, only 47% of high schools in America teach computer science. One solution may be to integrate computer science into other courses; and science courses, especially physics, are prime candidates for such an integration. But many teachers may be hesitant to integrate computer science for any number of reasons, including an unwillingness to cut content, a belief that students may not be capable of succeeding, or even lack of confidence in their own ability to program or teach programming. The author would like to share his experience weaving coding principles into both upper class and 9th grade physics classes at a New Jersey K-12-day school, and share stories and advice on overcoming obstacles to implementing a "computational physics" course. No coding experience required!

D1.04 | Introductory Courses

January 12, 2021 **| 11:30 AM - 12:45 PM**

D1.4-01 | Teaching Introductory Physics for Life-Science Majors with Student-Made Art

Presenting Author **|** *Stephanie Bailey, Chapman University*

Despite efforts to attract a broader student population into physics, introductory physics courses remain a deterrent for many students. The motivation for this book is to make introductory physics more accessible and to increase interest in the subject by incorporating art-based teaching at the undergraduate level. By providing an alternate mental pathway to access physics, students can deepen their personal connection with this often-impersonal subject. Additionally, by taking a visual approach to the study of physics, we can achieve a more inclusive way of teaching. This book focuses on the subject of electricity and is the first in a series of introductory physics topics. It is a collection of student-made artistic representations of physics concepts and accompanying student explanations of how the concept is explained more clearly through their art. Students were life-science majors enrolled in the introductory physics sequence at the University of California, Santa Cruz.https://www.blurb.com/b/10219506-teaching-physics-with-student-made-art

D1.4-02 | How Helpful are Different Study Methods for Physics Exams?

Presenting Author **|** *David Waters, University of Health Sciences and Pharmacy in St. Louis*
Additional Author | *Rahul Jilakara, University of Health Sciences and Pharmacy in St. Louis*

Studying for physics exams can be difficult and stressful, especially for a student's introductory year in physics. For students who don't plan to major in physics, the desire to do well is based less on understanding concepts and more on achieving a better grade. For this reason, students want to study as efficiently as possible by using the most optimal study methods. We've taken surveys over the past three years to determine how students' study for exams and compared that to their exam grades. We found that students who studied using methods that they rated as more helpful did better on the exams. By utilizing the study results, we are able to present our current, as well as future, students with study methods that have been rated as being more helpful and give them advice on ways to optimize their study time for their exams.

D1.4-03 | Prevalence and Prevention of Cheating in Online Introductory Physics Quizzes

Presenting Author **|** *Melanie Good, University of Pittsburgh*

For many large-enrollment introductory physics classes, the COVID-19pandemicraises the question of how to ensure academic honesty in online assessments. Short quizzes may help prevent student utilization of third party ``tutoring'' services to receive solutions. However, short quizzes could be vulnerable to students sharing quiz information. Given the pervasiveness of social media, smart phones, and other messaging services such as GroupMe, sharing of information could represent a significant source of cheating. In this investigation, the prevalence of this kind of cheating was explored by way of planted ``correct'' answers. The frequency of use of the plants was measured to determine a baseline level of students who received unauthorized quiz information from classmates. Interventions to promote academic honesty were then administered and a subsequent quiz was used to measure the effectiveness of these interventions. Finally, the prevalence and ways in which students provide quiz information to other students was probed.

D1.4-04 | Utilizing Head Fake Learning to present Introductory Physics Concepts

Presenting Author **|** *Justin Hadad, University of North Carolina at Chapel Hill*
Additional Author | *Dan Young, University of North Carolina at Chapel Hill*

Educators teach concepts in exciting ways to mask the extent that students think they are learning ostensibly uninteresting or inapplicable material. "Head-fake learning" ("HFL") describes the means by which material can be taught wherein students think they are learning one thing, but in fact are learning another—for example, this means that they learn academic material while playing games or engaging in seemingly non-academic work. Two physics courses, one at Gustavus College and another at UNC Chapel Hill, have trialed HFL mechanisms through the playing of games and study of game shows in class and we have prepared instructional databases which house educational material, and examples of games which can facilitate the delivery of this material. We provide instructions for their use in this presentation and analyze the effectiveness of such material in the classroom— holistically, students reported high learning efficiency and appreciated the ability to enjoy the learning experience.

D1.4-05 | Enhancing Student Engagement via a Monitored Student-Student Discussion Board

Presenting Author **|** *Sujata Krishna, University of Florida*
Additional Author | *Jeffrey Feldman, University of Florida*
Additional Author | *Una Milovanovik, University of Florida*

I report on two synchronous online courses: an algebra-based introductory Applied Physics I course to a broad-spectrum of non-physics majors, and an algebra-based Physics II course to post-baccalaureate pre-Health students. Active learning has been established in these courses in the form of small group problem solving sessions with Teaching/Learning Assistants. Additionally, I developed an active, graded discussion board. Experienced learning assistants worked with me to post open-ended questions for students, approximately once a week for the first few weeks. The aim was to get a dialogue going among students themselves after the initial weeks of prompting. They were encouraged to help one another with tips on homework questions. Part of the aim was to get students to use physics terminology. This resulted in several interesting threads revealing areas of misconception. I will highlight some of these discussions and report on how peer-discussion can enhance learning outside of class time.

D1.4-06 | The Fresnel Biprism Experiment Based on CMOS Imaging Analysis

Presenting Author **|** *Yan Cen, Fudan University*
Additional Author | *Zhengyang Zhao, Fudan University*

The measurement of the wavelength of a monochromatic source of light with the Fresnel's biprism is a fundamental experiment in most Universities. In this experiment, the determination of distance between two virtual light sources is necessary for the calculation of the wavelength of light. However, the presence of the aberration of lens results in an erratic distance between virtual source by using conjugate foci method, which leads to an erratic wavelength. To solve this, we used a CMOS detector to record magnified images and diminished images. The accurate distance between two virtual light sources was obtained with digital images processing, thereby reducing the uncertainty of measurement of the wavelength. The deviation between the measured wavelength of sodium light from CMOS imaging analysis method and the average wavelength at 589.3nm calculated by two wavelengths ofsodium yellow light is only 0.3%, which is smaller than the deviation from traditional method.

D1.4-07 | Effectively Implementing Peer Review into Introductory Physics Laboratory Courses

Presenting Author **|** *William Poteet, Western Kentucky University*
Additional Author | *Scott Bonham, Western Kentucky University*

We are conducting out a study to evaluate the effectiveness of structured peer review sessions on student writing skills in introductory physics laboratory courses. Preliminary data suggest that peer review sessions are more efficient for improving students' technical writing skills. Previously, students were expected to write weekly lab reports over different experiments without peer communication or review. We have now implemented a writing instruction method in which students produce three reports throughout the semester that undergo peer review by fellow students, then are revised based on the feedback they receive, and finally submitted to the instructor for grading. Following a research protocol previously applied to non-peer review student writing, we will be able to compare the effectiveness of both methods.

D1.4-08 | Advanced Fitting and Uncertainty Analysis in Introductory Physics

***Presenting Author* |** *Duncan Carlsmith, University of Wisconsin - Madison*

Physics students generally encounter only rudimentary concepts of measurement uncertainty analysis in an introductory university physics course. This talk presents a physics-forward more advanced introduction to probability and statistics beginning with loaded dice and chaos concepts in a computational tutorial for first year physics and astronomy students. Subsequent tutorials provide a rigorous frequentist interpretation of nonlinear curve fitting parameters and uncertainties used throughout their laboratory data analysis. Other topics such as Monte Carlo techniques are touched upon. These tutorials and student lab data analysis makes use of MATLAB.

D1.05 | PER: Student Content Understanding, Problem-Solving and Reasoning

January 12, 2021 **| 11:30 AM - 12:45 PM**

D1.5-01 | A Study on Misconceptions of Mathematics and Science Teachers

***Presenting Author* |** *Maia Magrakvelidze, Cabrini University*
Additional Author | Michece Oswald Ann, Cabrini University
Additional Author | Hossein Shahrtash, Cabrini University

In this joint study, we try to uncover the common misconceptions amongst the educators that result from a lack of understanding of the underlying principles involved in the construction of mathematical and scientific concepts. We seek to raise awareness to the issue to provide support to mathematics and science educators in correcting their own misconceptions as well as strategies for identifying and correcting misconceptions held by their students. Research shows that teachers who understand their student's common misconceptions are more likely to design instruction that will increase student understanding in the subject than teachers who do not. Additionally, teachers with misconceptions themselves unknowingly contribute to the reinforcement of student misconceptions during the teaching and learning cycle. Data will be collected online and anonymously across the state and the country. The target participants include mathematics and science educators in universities, middle and high schools as well as pre-service Mathematics teacher candidates.

D1.5-02 | Multidimensional Item Response Theory and the BEMA

***Presenting Author* |** *John Hansen, West Virginia University*
Additional Author | John Stewart C, West Virginia University

The Brief Electricity and Magnetism Assessment (BEMA) is a 31-question assessment designed to assess student understanding of basic principles of electricity and magnetism in an introductory, calculus-based physics course. This study develops a model of student knowledge measured by the BEMA. This is guided by a theoretical model of expert understanding of electricity and magnetism. Multidimensional Item Response Theory (MIRT) was used to investigate a large post-test dataset (N=9666) from a large, western public research university collected over the span of 15 years. An optimal model was found by exploring variations to the theoretical expert model and selecting the model with the optimal MIRT fit parameters.

D1.5-03 | Educational Augmented Reality: Interactive Magnetic Field Visualization

Presenting Author **|** *Michael Herkommer,*
Additional Author **|** *Beth Thacker, Texas Tech University*

Most research into educational augmented reality (AR) has centered around students' attitudes toward the new technology, and not how effective AR is at increasing students understanding. This project compares improvements in student understanding between a three-dimensional AR visualization and the traditional two-dimensional visualization. We included an interactive AR simulation in the magnetism unit in one section of a laboratory-based, algebra-based introductory physics class. We selected a common exam problem that requires 3-D visualization of a magnetic field and compared the results of the treatment and control groups. We discuss the app, present results and present plans for future research.

D1.5-04 | Consistency of Students' Mathematical Difficulties May Allow Reliable Performance Predictability

Presenting Author **|** *David Meltzer, Arizona State University*
Additional Author **|** *Dakota King H, Arizona State University*

Our investigation of introductory physics students' difficulties with pre-college mathematics has extended to five campuses at four universities, employing a 14-item diagnostic administered near the beginning of the semester. More than6000 students have taken the diagnostic over the past four years. We find (1) consistently high error rates (30-70%) on trigonometry, algebra, geometry, and graphing problems, (2) significant degradation of algebra performance when symbolic coefficients are substituted for numerical coefficients, and when Greek letters are substituted for Latin letters, and (3) high performance consistency among diverse question types, such that performance on a single test item can reliably predict overall diagnostic performance. A new online version of the diagnostic has been tested with small samples and seems to produce results that are largely consistent with the written version. Performance on non-mathematical conceptual physics questions, added to the online diagnostic, is significantly correlated with performance on the mathematics questions.

Supported in part by NSF DUE #1504986 and #1914712

D1.5-05 | Introductory Physics Students' Mathematical Preparedness and Conceptual Understanding of Force

Presenting Author **|** *Dakota King, Arizona State University*
Additional Author **|** *David Meltzer E, Arizona State University*

Over the past four years, we have administered over 6, 000 mathematics diagnostics to introductory physics students at four large state universities. Previously, our hand-written diagnostic only included pure mathematics problems in graphing, trigonometry, geometry, and algebra. While these problems have shed light on the severity and nature of students' mathematical difficulties, our new online diagnostic aims to also measure performance on conceptual physics problems (Newton's second and third laws). We find the mathematics portion of our online diagnostic shares the same characteristics as older hand-written versions with similar correct-response rates, internal consistency, and performance predictability. Our analyses show that overall mathematics performance is correlated with performance on the newly added physics problems (r=0.35). Here, we present our most recent findings while examining the observed relationship between math and physics performance.

Supported in part by NSF DUE #1504986 and #1914712

D1.5-06 | Impact of an Angular Momentum Problem-solving Tutorial on Student Performance*

Presenting Author **|** *Alexandru Maries, University of Cincinnati*
Additional Author | *Kathleen Koenig, University of Cincinnati*
Additional Author | *Robert Teese, Rochester Institute of Technology*
Additional Author | *Michelle Chabot, Rochester Institute of Technology*

Under NSF funding we have been developing and evaluating Interactive Video-Enhanced Tutorials (IVETs) which are designed to help students learn to use expert-like problem-solving strategies for college students in introductory physics. The tutorials involve web-based activities which lead students through a solution by providing guidance and feedback depending on the choices they make within the activities. This presentation will showcase one of our IVETs, namely Angular Momentum, and provide details about its design features, which involve multimedia principles of learning and research on human learning and memory, and subsequent impact on student problem-solving abilities.

**Work supported by the NSF IUSE Program (DUE #1821396)*

D1.5-07 | Discussion of Selected Alternate Conceptions about Buoyancy in College Populations

Presenting Author **|** *DJ Wagner, Grove City College*
Additional Author | *Caleb Barber, Grove City College*

As a part of our larger research on students' conceptions on fluids, our group has been developing a taxonomy categorizing alternate conceptions about buoyancy and giving assessments in various introductory courses to determine the prevalence of selected taxonomy items. This talk will focus on a few of those taxonomy items, discussing the populations in which they were identified and how they relate to the overall taxonomy construction.

D1.5-08 | Prevalence of Selected Alternate Conceptions about Buoyancy in College Populations

Presenting Author **|** *Caleb Barber, Grove City College*
Additional Author | *DJ Wagner, Grove City College*

As a part of our larger research on students' conceptions on fluids, our group has been developing a taxonomy categorizing alternate conceptions about buoyancy and giving assessments in various introductory courses to determine the prevalence of selected taxonomy items. This talk will focus on the results of selected assessment questions given to multiple introductory physics courses at Grove City College; some questions were also given to students at the University of Washington. The prevalence of each alternate conception probed will be discussed, along with similarities and differences between the populations.

D1.5-09 | Introductory Students' Qualitative Analysis of the Brachistochrone

Presenting Author | Drew Milsom, University of Arizona

While the classic brachistochrone problem is too complicated to solve in an introductory course, students should be able to understand the qualitative features of the problem. We asked the students a number of questions about this problem. For this talk, we will focus on the following question "Explain how it is possible for the mass to start from rest at different points along the cycloid and still reach the bottom at the same time." Their answers display a wide variety of misconceptions and we will highlight some specific answers during this talk.

D1.06 | POGIL and Teaching Methods from other Disciplines

January 12, 2021 **| 11:30 AM - 12:45 PM**

Sponsor: *Committee on Physics in Pre-High School Education*
Co-Sponsor: *Committee on Physics in High Schools*

D1.6-01 | POGIL-inspired Roles for Small Groups and Other Group Management Techniques

Presenting Author | *Kristin Wedding Crowell, CSU-East Bay*

We will present our experience assigning specific roles to each member of student groups to assist them with group dynamics when working through cooperative laboratory tasks. The initial implementation was inspired by an introductory POGIL seminar given to science faculty. Connections will be made to the work done by the Hellers from the University of Minnesota on Group Problem Solving Strategies in introductory physics classes. We will also present results of informal polling of our Faculty Online Learning Community (FOLC) on techniques for forming effective groups. This is part of a series of talks stemming from the NextGen PET FOLC project. This work was supported by the National Science Foundation grant NSF DUE-1626496.

D1.6-02 | Frayer Model: A Digital Format for Synchronous Learning

Presenting Author | *Ann Daniel, LaBelle High School*

The Frayer Model is a reading strategy presented as a graphic organizer. Researchers have shown that the approach promotes vocabulary development for specified scientific terms among high school students. This empirical research study sought to explore a way to develop scientific vocabulary among English Language Learners and Students with Disabilities in a synchronous learning environment between in-person and virtual learners by implementing the Frayer Model in a digital format using Google Slides. Google Slides settings allow each student to interact independently with the content while simultaneously sharing with the group. A convenience sample consisted of eleven high school students, seven in-person learners, and four virtual learners. Daily bellwork composed of one question provided post data to assess retention and understanding. Observational data captured in reflective logs shows increase active learning, and students form personal connections between the scientific terms and their personal experiences.

D1.6-03 | Bringing Argument-Driven Inquiry into IPLS labs

Presenting Author **|** *Jason May, University of Utah*
Additional Author | Claudia De Grandi, University of Utah
Additional Author | Adam Beehler, University of Utah
Additional Author | Jordan Gerton, University of Utah

Argument-Driven Inquiry (ADI) is an instructional model which originated in Chemistry education and provides students opportunities to develop and carry out their own experimental designs while engaging in argumentation and peer review. In 2019, we adopted a modified ADI instructional model into our Introductory Physics Labs for Life Sciences (IPL2S) courses to include a more formal structure for student engagement in scientific practices as part of three-dimensional learning. In this talk, we introduce the ADI instructional model, discuss integration of the ADI instructional model into our reformed lab course, and describe recent impacts it has had on our course. Specifically, we present how our modified ADI model has: 1) enhanced student engagement in scientific practices, specifically experimental design planning and scientific argumentation; 2) aided in the shift to online instruction while maintaining course learning outcomes; and 3) provided pedagogical consistency in a course with rotating instructional faculty.

D1.6-04 | What Happens When Hamilton's Principle Meets Massless Model Engineering Systems?

Presenting Author **|** *John Sanders, California State University - Fullerton*

The principle of stationary action, more commonly known as Hamilton's principle, represents a milestone in the undergraduate physics curriculum. A common question students ask is whether the Hamilton action achieves a local minimum, a local maximum, or a saddle point. It has long been known that, for systems with nonzero mass, there is no worldline for which the action achieves a local maximum. However, so-called "massless" systems do appear in engineering, where they are used to model components of negligibly small mass (such as very light springs or very light wheels). Inspired by these engineering examples, the present work investigates the stationary character of the Hamilton action in the non-relativistic limit of vanishing mass. It is shown that, in that limit, it is mathematically possible for the action to achieve a local maximum. This paper discusses the benefits of this exercise, which can be implemented in any classical mechanics course.

D1.6-05 | Teaching Special Theory of Relativity Using the History of Science

Presenting Author **|** *Hafedh Trabelsi, Aix-Marseille Université*

In Tunisia, the current teaching of physical sciences at all school levels (primary, secondary and university) does not take into account the teaching of the history of science, despite the results of research (JLMartinaand, 2001), (Guedj, 2005), (C. De Hosson, 2011) who confirmed the interest of the introduction of the history of science in improving the learning outcomes of learners and the power to overcome learners' disaffection with scientific studies. The teaching of special theory of relativity, which is often synonymous with complexity and incomprehension by teachers and learners, has been eliminated from official Tunisian physical science curricula in secondary schools since 1998.How will we be able to introduce this theory to students despite the difficulties presented? The answer to this question is to appeal to the history of science and in particular the history of relativity without the use of a heavy mathematical formalism.

D1.6-06 | | Association of Concave Spherical Mirrors

Presenting Author **|** *Abbas Abbasi*

Students reflect all rays parallel with the main axis in a spherical concave mirror to draw with a focal point that called real focal. In this paper we prove that the geometric method with a primary focus of rays parallel with the main axis of a spherical surface, is not a point.

D1.09 | Making Physics Labs More Accessible: Perspectives of Former Physical Science Students

January 12, 2021 **| 11:30 AM - 12:45 PM**

D1.09 | Making Physics Labs More Accessible: Perspectives of Former Physical Science Students

Moderators: *David Spiecker and Dimitri Dounas-Frazer*
Panelists: *Erin Scanlon, Jamie Principato Crane, Daniel Gillen, L. C. Osadchuk*

One of two complementary panels dedicated to raising awareness about improving the accessibility of undergraduate physics laboratory courses. In this panel, former physical science students about their previous and current experiences and/or expertise with accessibility in physics and physical science labs, and they make suggestions for improving accessibility of labs.] Physics labs are an exciting opportunity to teach and learn about physics by collaboratively planning, building, and carrying out experiments and interacting with advanced phenomena, apparatus, and software. Students, staff, and faculty with disabilities deserve full access to these learning environments, and it is everyone's responsibility to recognize and mitigate the specific barriers to participation posed by space, technology, and pedagogical constraints that are unique to labs. To that end (and with support from an AAPT Special Projects Grant), the AAPT Committee on Laboratories assembled a task force whose charge is to issue an open call for increased investment in accessible physics labs.

D1.10 | Applied Improvisation for Physics (Live Event)

January 12, 2021 **| 11:30 AM - 12:45 PM**
Sponsor: *Committee on Physics in Pre-High School Education*

D1.10 | Applied Improvisation for Physics

Presenting Author **|** *Carolyn Sealfon*

How can we help all our students experience what we love about physics, such as playful curiosity and the excitement of exploration? Join us for a participant-centered, laughter-filled session where we will engage together (online!) in active-learning exercises borrowed from improvisational theater (improv) to practice skills such as creativity, listening, communication, collaboration, and resilience. We will then debrief on how we can integrate and adapt such exercises to enhance physics teaching and learning.