# Physics Education Research Conference
# PERC 20/20

## Insights, Reflections, & Future Directions:
## Emergent Themes in the Evolving PER Community


Join us as we explore emergent themes in PER as a scholarly endeavor and as a research community!

Since its inception, PER has served as a confluence of discipline, theory, research methodology, practice, and application. How have these facets and the interplays among them been fruitful for physics education globally, regionally, locally, or otherwise? And, how have our successes and interactions influenced the very nature of PER itself?

Critically important, too, are context and environment. We acknowledge that historically, global landscapes of unrest, uncertainty, injustices, loss, and hardships impact us in a myriad of ways. Coupled with recent events, we recognize this exacerbates challenges many face. Whatever your circumstances might be, we appreciate that you are here with us and are keeping those in our community who are unable to attend in our thoughts.

A tenet of the PERC 20/20 was to begin new conversations, revisit old conversations and to keep them all going. Messages and interactions on our blog and Twitter feed had this intent at heart. We hope you will continue to contribute to the content of these forums in the weeks and months ahead!

PERC 20/20 Blog

@perc2020, #perc2020

Respectfully,

Alexis Knaub
Steve Maier
Lin Ding
Beth A. Cunningham

# At-a-glance Schedule

| Wednesday, July 22, 2020 | | Page |
|---|---|---|
| 2:30pm | **Bridging Session Q&A --** *Geraldine L. Cochran, Joseph Krajcik, Sarah B. McKagan, Valerie K. Otero, Susan R. Singer, Robert H. Tai* | 4 |
| 3:30pm | Poster Session I:<br>Odd posters present during the first half hour. Even posters present during the second half hour. | 6 |
| 4:30pm | Snack & Chat (live breakout rooms using gather.town through PERC program on underline.io) | 44 |
| 5:30pm | End of PERC Day 1 | |

| Thursday, July 23, 2020 | | Page |
|---|---|---|
| 10:00am | • Establishing scientific norms in the lab: a spotlight on the instructor<br>• Expanding your network: IPER Community buildathon<br>• Juried Talks I<br>• Recent results on classroom effectiveness of Virtual Reality and Augmented Reality technology<br>• Students' Understanding of Fluids<br>• What was, is and will be Physics Education Research | 15<br>18<br>19<br>21<br>23<br>25 |
| 11:00am | Poster Session II:<br>• Odd posters present during the first half hour. Even posters present during the second half hour. | 9 |
| 12:00pm | • Diverse Career Paths in Physics Education: A Panel Discussion<br>• Evaluation of Innovative Reforms in Upper Division Physics Courses<br>• Future directions in PER: Reflecting critically on student success<br>• Juried Talks II<br>• Using the theory of conceptual blending at the mathematics-physics interface | 26<br>27<br>29<br>31<br>33 |
| 1:00pm | • All things Get the Facts Out: Perceptions, emotionally compelling messages, and data mining<br>• Assessing Teaching Effectiveness: We Need More Than Just Student Evaluations<br>• Juried Talks III<br>• Measuring and improving PCK of student assistants in introductory physics classes<br>• Promoting Successful Change in Physics Education and Research | 35<br>37<br>39<br>41<br>42 |
| 2:00pm | Poster Session III:<br>• Odd posters present during the first half hour. Even posters present during the second half hour. | 12 |
| 3:00pm | Closing Session (live online format) | |
| 3:30pm | Open Conversation (live online format) | |
| 4:00pm | End of PERC | |

**All times are Eastern Daylight Time (EDT)**

## Useful Links

### Conference specific

- Underline Conferences
  - to access PERC online events
- "How to navigate the Underline platform" YouTube video by Stephanie Williams
- perc2020@underline.io
  - for technical questions regarding accessing PERC online content, troubleshooting website errors
- perconference2020@gmail.com
  - to contact organizers with conference related topics or issues (provide feedback, comments, cc: correspondence with Underline if you like)
- PERC 20/20
  - Online Schedule
  - Blog
  - Abstract Search
- PER Conference Series (1997 – Present)

### Original host city of Grand Rapids support

With the change in format and venue of a physical conference to a virtual conference, members of the AAPT & PER communities recognize that the host city of Grand Rapids will incur an economic impact. For those who would like to make a contribution to offset these hardships, here is information and links.

- To donate through AAPT so that funds go to Grand Rapids area hospitality workers: https://www.aapt.org/Conferences/SM2020/registrationpage.cfm
- To donate to the Michigan Restaurant and Lodging Association Educational Foundation (MRLAEF) for funds to be distributed statewide: https://mrlaef.org/relief-fund.html
- To donate to the Kent County COVID-19 Recovery Fund to help communities who are identified as most in need in the Grand Rapids area: https://www.grfoundation.org/give/covid19

## Bridging Session

## Wednesday, July 22, 2:30PM EDT

**Dr. Geraldine Cochran** is an Assistant Professor with a joint position in the Department of Physics and Astronomy and the Office of STEM Education at Rutgers University. Cochran is a physics education researcher. Her research spans a variety of topics including course transformation in introductory math and physics courses, broadening participation in STEM, and creating collaborative and inclusive classroom spaces. Cochran is committed to equity and social justice and is active at local and national levels in addressing inequities and injustice in STEM.

**Joseph Krajcik** serves as director of the CREATE for STEM Institute and is the Lappan-Phillips Professor of Science Education at Michigan State University. In his role as director of CREATE, he works with faculty, teachers and researchers to improve the teaching and learning of science, mathematics and engineering kindergarten through college by engaging in innovation and research. Joe served as president of the National Association for Research in Science Teaching from which he received the Distinguished Contributions to Science Education Through Research Award in 2010. In 2014 he received from Michigan Science Teachers' Association the George G. Mallinson Award for overall excellence of contributions to science education. He was honored to receive a Distinguished Professorship from Ewha Woman's University in Seoul, South Korea in 2009, Guest Professorships from Beijing Normal University in Beijing, China in 2002 and 2018, and the Weston Visiting Professor of Science Education from Weizmann Institute of Science, Israel in 2005. In 2019 Joe has been elected to the National Academy of Education, an honor received for the nation's most outstanding scholars in education.

**Sam McKagan** is the creator and director of PhysPort, a website that supports physics faculty in using research-based teaching and assessment in their classes and departments. She also serves as design and development director for the Living Physics Portal, an online community for sharing and discussing materials for physics for life sciences, and the editorial director for the Effective Practices for Physics Programs (EP3) project, which is developing a guide to support physics department chairs in using effective practices for the ongoing review and improvement of their programs within the context and constraints of their local environment. She consults for universities and professional societies across the country on user-centered design, faculty professional development, and video analysis of physics classrooms.

**Valerie Otero** is a professor of Science Education at the University of Colorado Boulder. She is co-founder (with Richard McCray) and executive director of the Colorado Learning Assistant (LA) program and the International LA Alliance. She has co-authored several physics curricula including Physics through Evidence, Empowerment through Reasoning (PEER Physics) and Physics and Everyday Thinking. Otero has advised the NAS, NASA, and APS on issues in physics education and physics teacher preparation. She has published broadly on physics education research and the history of physics education reform. Otero's programs use science to help learners advocate for themselves through the use of evidence. Otero is a Chicana, first generation college student, committed to building and sustaining equitable and relevant science learning environments.

Prior to becoming Vice President for Academic Affairs and Provost at Rollins, **Susan Singer** was Division Director for Undergraduate Education at NSF and Gould Professor of Biology at Carleton, where she directed the Perlman Center for Learning and Teaching. She pursues a career integrating science and education aimed at improving undergraduate education at scale, including research on networks of organizations working to advance undergraduate STEM education. Susan is a AAAS fellow, and recipient of the American Society of Plant Biology teaching award and Botanical Society of America Charles Bessey award. She is past-chair of AAAS' Education Section and serves on the National Academies of Science, Engineering, and Medicine's Roundtable on Systematic Change in Undergraduate STEM Education and the Board on Life Sciences. She chaired the several National Academies' studies, including Discipline-based Education Research.

**Robert H. Tai** is an associate professor of education at the Curry School of Education and Human Development at University of Virginia. Prof. Tai has focused his research agenda on understanding how to better engage youth in science and science learning. Through his work, he has developed tools for measuring youth science engagement in both formal and informal settings. He is currently involved with several research studies including collaborations with the Museum of Science and Industry in Chicago and the Space Science Institute in Boulder, Colorado. His work has been published in journals such as *Science*, *Science Education*, and *Journal of Science Research and Teaching*. In Summer 2018, the National Afterschool Association named Dr. Tai among its "Most Influential in Research and Evaluation." He is currently Co-Editor of the *Science Educator* and on the editorial board of the *Journal Science Education and Technology*.

## Poster Session I
## Wednesday, July 22, 3:30pm EDT

Underline Conferences

| | | |
|---|---|---|
| Allen, Patricia E. | Longitudinal E-CLASS Study of Physics Majors at a Masters-granting, Comprehensive University | 1.K4 |
| Amin, Bahar | STEM Students' Self-Efficacy and Sense of Belonging in Introductory Physics Labs | 1.G3 |
| Amos, Nathaniel | Excerpts from an exploratory survey of units/dimensional analysis in introductory physics | 1.L2 |
| Barthelemy, Ramon | Graduate programs in physics education research: A USA based survey | 1.I1 |
| Blackmon, Lena | Characterizing the mathematical problem-solving strategies of advanced novice physics students | 1.M4 |
| Bott, Theodore E. | Navigating computational thinking practices for high school physics curricula | 1.E1 |
| Breakall, Jared B. | Maybe we aren't that different after all: Faculty perceptions of grade 7-12 teaching as a career | 1.D4 |
| Burkholder, Eric | Hidden variables: predicting student performance in introductory physics | 1.C2 |
| Christman, Devon M | Supporting undergraduate facilitators to strengthen physics outreach programs | 1.C4 |
| Corsiglia, Giaco | Characterizing and monitoring student discomfort in upper-division quantum mechanics | 1.N3 |
| Cwik, Sonja | How the learning environment predicts male and female students' motivational beliefs in algebra-based introductory physics | 1.F5 |
| Dalka, Robert | Scaffolding Collective Reflection in a Physics Education Research Group | 1.I3 |
| Doucette, Danny | What Makes a Good Physics Lab Partner? | 1.A4 |
| Dounas-Frazer, Dimitri R. | Student perceptions of laboratory classroom activities and experimental physics practice | 1.A3 |
| Dreyfus, Benjamin W | Longitudinal impact of flipped and traditional introductory physics courses | 1.D1 |
| Eblen-Zayas, Melissa | Supporting student quantitative skills across introductory STEM courses: faculty approaches and perceived needs | 1.E2 |
| Fields, Melanie | The transition to online teaching during the COVID-19 pandemic at a regional, rural university: The experience of learning assistants | 1.J4 |
| Fischer, Christopher | Changing pedagogy to help traditionally under-served populations | 1.C5 |
| Gray, Nickolas | What do Students Know about Electromagnetic Wave Generation? | 1.N5 |
| Guthrie, Matthew | A tale of two guessing strategies: interpreting the time students spend solving problems through online log data | 1.L1 |
| Gutmann, Brianne | "I'm not that important": Barriers and bolsters to student agency during conversations about the intersections of physics and ethics | 1.E4 |
| Her, Pachi | Examining student understanding of matrix algebra and eigentheory | 1.N1 |
| Izadi, Dena | Physics Communication through Art: Development of Intersecting Identities | 1.J1 |
| Jambuge, Amali Priyanka | Assessment feedback: A tool to promote scientific practices in upper-division | 1.K5 |
| Jeon, Sophia | How do gender and inchargeness interact to affect equity in lab group | 1.B1 |

| | | |
|---|---|---|
| | interactions? | |
| Keebaugh, Christof | Investigating student understanding of the stationary state wavefunction for a system of identical particles | 1.L3 |
| Lassen, Ira Ché | Student ownership of lab projects: manifestation in student-project interactions | 1.B4 |
| Liu, Raylor | Modeling the Complexity of Change and Implications of Sensemaking | 1.E3 |
| Lo, William | Insights into student understanding of statistical mechanics | 1.N4 |
| Marshman, Emily | Improving student understanding of Dirac notation by using analogical reasoning in the context of a three-dimensional vector space | 1.M3 |
| Martin, Makenna M. | A tool for documenting and analyzing the flow of conversation about teaching and learning in facilitated faculty conversations | 1.H2 |
| Mason, Andrew J. | Attitudes and approaches towards physics problem solving: by life science major, by course sequence, and by shutdown status | 1.K2 |
| McColgan, Michele | Team-based learning in physics courses | 1.C3 |
| Mellen, Jillian | Qualitative analysis of student perceptions of their self-efficacy | 1.D3 |
| Mikota, Matthew | Workplace Climate for LGBT+ Physicists: Predictor of Outness | 1.J2 |
| Mondesir, Raphael | Toward characterizing the demographics of introductory physics courses | 1.I2 |
| Ota, Shuya | New measurements of BEMA performance based on the classical test theory | 1.K3 |
| Patterson, Zac | Students' pre-instructional perspectives of quantum physics | 1.M5 |
| Pearson III, Richard L | Results of faculty interviews during the development of the Perceptions of Teaching as a Profession in Higher Education (PTaP.HE) instrument | 1.H3 |
| Pollard, Benjamin | MAPLE, the Modeling Assessment for Physics Laboratory Experiments | 1.B3 |
| Quichocho, Xandria R. | Understanding physics identity development through the identity performances of Black, Indigenous, and women of color and LGBTQ+ women in physics | 1.F2 |
| Rainey, Katherine D | Developing coupled, multiple-response assessment items addressing scientific practices | 1.N2 |
| Ramey II, Charles L. | Comparative analysis of letters and reports in an upper-division lab | 1.B5 |
| Ramírez Díaz, Mario Humberto | Analysis of the evolution and results of Physics Teacher Professional Development projects for Preschool | 1.H4 |
| Rios, Laura | Analysis of students perceptions of classroom structure, belongingness, and motivation in an introductory physics course | 1.G1 |
| Rodriguez, Miguel | The associations between conceptual learning, physics identity and social interdependence | 1.F1 |
| Ryan, Qing | Question Characteristics and Students' Epistemic Framing | 1.M2 |
| Sagear, Sheila | Student learning outcomes with hybrid computer simulations and hands-on labs | 1.B2 |
| Salehi, Shima | Implicit and unchecked assumptions interfere with problem-solving in physics | 1.L4 |
| Sammons, Amber | Changes in student attitudes and curricular benefits as a new course activity becomes standard | 1.G5 |
| Sayer, Ryan | Advanced students' and faculty members' reasoning about the double slit experiment with single particles | 1.M1 |

| | | |
|---|---|---|
| Singh, Chandralekha | Why equivalent structural equation models of physics identity have different instructional implications | 1.F3 |
| Smith, Emily M. | "Let's just pretend": Students' shifts in frames during a content-reinforcement lab | 1.A1 |
| Stang, Jared | Exploring the contributions of self-efficacy and test anxiety to gender differences in assessments | 1.K1 |
| Strubbe, Linda E. | PhysPort as professional development to foster creativity in teaching | 1.H1 |
| Sundstrom, Meagan | Problematizing in inquiry-based labs: how students respond to unexpected results | 1.A2 |
| Thacker, Beth | Development of an Instrument to Measure Student Assistants' PCK-Q | 1.H5 |
| Topdemir, Zeynep | Students' integration related to recognition | 1.F4 |
| Trucks, Jesica L. | Extending Learning Beyond the Planetarium with the Dome+ Model | 1.J3 |
| Van Dusen, Ben | A critical examination of DFW rates in LA supported physics courses | 1.C1 |
| White, Courtney | Student evaluation of more or better experimental data in classical and quantum mechanics | 1.A5 |
| Wood, Laura A. H. | Transfer Student's Narrative of Groupwork Characterized by Research Methods Course | 1.G2 |
| Young, Nicholas T. | The Physics GRE does not help "overlooked" applicants | 1.D2 |
| Zhang, Muxin | Examining the Social Dynamics of Small-Group Discussions | 1.E5 |
| Zimmerman, Charlotte | Exploring student facility with "goes like" reasoning in introductory physics | 1.L5 |

## Poster Session II
## Thursday, July 23, 11:00am EDT

Underline Conferences

| | | |
|---|---|---|
| Akinyemi, Abolaji | A tale of two approaches: Comparison of evaluation strategies in physics problem solving between first- and third-year students | 2.L4 |
| Altermatt, Ellen | Teaching Experience, Community of Practice Beliefs, and Teaching Strategies Predict Perceived IPLS Course Effectiveness | 2.E2 |
| Bayat Barooni, Amin | Investigating student design engagement in research-based activities | 2.C3 |
| Bradbury, Forrest R. | Open-inquiry experiments using sensors controlled by Arduinos in a pandemic-resilient lab course | 2.C1 |
| Burde, Jan-Philipp | Evaluating secondary school students' interest and conceptual understanding of circuits | 2.G4 |
| Cao, Ying | Shared Resources in Student Understanding of Spherical Unit Vectors in Upper-division E&M | 2.J5 |
| Cardinot, Adriana | An investigation of Irish students' alternative conceptions of astronomy | 2.I4 |
| Chen, Zhongzhou | Exploring the relation between students' online learning behavior and course performance by incorporation of contextual information in data analysis | 2.I1 |
| Cochran, Geraldine L | A framework for improving diversity work in physics | 2.A4 |
| Cowan, Erika | Using Deliberate Innovation Methodologies to Enable Graduate Student Success | 2.H1 |
| Doty, Constance M. | Impact of changing physical learning space on GTA and student behaviors | 2.E1 |
| Dreyfus, Benjamin W | How the Learning Assistant Experience Impacts Learning Assistants as Students | 2.B2 |
| Euler, Elias | The digital technologies of physics education research | 2.A1 |
| Frazer, Laszlo | "It's Fundamental": Quantum Dot Blinking Experiment to Teach Critical Thinking | 2.C5 |
| Hamdan, Alia | Lightning changes amidst Covid-19: A case study of how a large research institute moved physics classes and labs online and its impact on students and | 2.D5 |
| Head, Thomas | Believe that they can achieve: How Teacher Attitudes Toward Physics Impact Student Outcomes | 2.G5 |
| House, Lindsay | Legacy of the Pale Blue Dot: Can introductory astronomy experiences impact mindset and self-efficacy? | 2.H5 |
| Hull, Michael M | Respecting fluidity of student ideas: student-centered and enjoyable lessons about radioactivity | 2.M6 |
| Ibrahim, Bashirah | Students' visual gaze in solving sequential and simultaneous synthesis problems | 2.F1 |
| Jia, Ying | Improving student understanding of a rigid body rolling without slipping | 2.K2 |
| Johnson, Brandon James | A Case Study Exploring Reasons a Hard-Working Student Might Copy from Yahoo Answers | 2.J4 |
| Johnson, Nekeisha | Examining consistency of student errors in vector operations using module analysis | 2.L1 |
| Kalender, Z. Yasemin | Sense of agency, gender, and students' perception in open-ended physics labs | 2.D2 |

| | | |
|---|---|---|
| Kapp, Sebastian | Augmented Reality Visualizations in Undergraduate Physics Laboratory Courses | 2.D4 |
| Kepple, Caitlin | Pedagogy training for the development of GTA mindsets and inclusive teaching practices | 2.B1 |
| Khong, Hien | Examining students engagement in Planning Investigations practice in a written exam | 2.C4 |
| Leak, Anne E. | The influence of teacher questioning approaches on students' productive thinking | 2.M1 |
| Leuteritz, Robyn | Investigating the Impact of Cognitive Training on Newton's 2nd Law | 2.M3 |
| Li, Yangqiuting | How learning environment predicts male and female students' physics motivational beliefs in introductory physics courses | 2.J1 |
| Liu, Dan | Decomposition of forces on inclined planes | 2.L3 |
| Malespina, Alysa | The additional benefit of working in same-gender groups on students' self-efficacy in introductory physics | 2.J2 |
| Maries, Alexandru | Promoting Problem-Solving Abilities through Web-based Interactive Video-Enhanced Tutorials | 2.I2 |
| Mays, Mikayla | Examining and supporting student construction of alternative lines of reasoning | 2.M2 |
| McCauley, Austin | Understanding LA sensemaking: using "teacher hat" to prompt changes in discussion frame | 2.B4 |
| Mistades, Voltaire | Students' Conceptual Understanding and Problem-Solving of the Work-Energy and Impulse-Momentum Theorems | 2.K3 |
| Mitchell-Polka, Khadijih | The physics classroom as a space for empowerment | 2.A5 |
| Monsalve, Camila | Students of Color with transfer credits earn a large share of STEM degrees at Large Midwestern University: A quantitative study | 2.H2 |
| Morrison, Andrew | Comparison of student-reported study habits with faculty expectations and predictions | 2.M5 |
| Moshfeghyeganeh, Saeed | The Effect of Spirituality and Religiousness on Students' Physics Career Choice in the US | 2.H4 |
| Mullen, Claire | Computation for Science: Engaging university science students in computational thinking | 2.I5 |
| Nadeau, Michael | Participation in an online community of high school physics teachers | 2.G2 |
| Prefontaine, Brean | Informal Physics Programs as Integral Experiences for Physics Identity Development | 2.B5 |
| Rak, Gwendolyn | Exploring the Durability of Student Attitudes Toward Interdisciplinarity | 2.E5 |
| Ramírez Díaz, Mario Humberto | Research Projects in Science Education for Preschool, Evolution, and Results in Curriculum Development, Evaluation Tools, and Teacher Workshops. | 2.G1 |
| Rodelli, Liana | Analyzing the impacts of a new mobile application on student understanding of and attitudes toward electric fields | 2.K5 |
| Rosauer, Jeffrey Robert | Thematic analysis of student manipulations of the PhET simulation "Fluid Pressure and Flow" | 2.I3 |
| Rosenblatt, Rebecca | Investigating partnerships and funding for the Physics Education Research | 2.A2 |

| | | |
|---|---|---|
| | community | |
| Roy, Anindya | Colorado Learning Attitude about Science Survey: Does attitudinal shift mean what we think? | 2.F3 |
| Rubien, Jack D | The impact of IPLS in a senior biology capstone course | 2.E3 |
| Sarriugarte, Paulo | Students' understanding of the moment of inertia in a rotating rigid body | 2.K1 |
| Scanlon, Erin M. | Practicing physicists' knowledge about disability: Development of the Disability and Physics Careers Survey (DPCS) | 2.A3 |
| Shafer, Devyn | When the Gatekeeper Says No: Mechanics Students' Resilience and Success | 2.H3 |
| Sirnoorkar, Amogh | Qualitative Analysis of Students' Epistemic Framing Surrounding Instructor's Interaction | 2.M4 |
| Starita, Jason T. | What makes a person a physicist? Learning Assistant and physics major views | 2.B3 |
| Stump, Emily M. | Student reasoning about sources of experimental measurement uncertainty in quantum versus classical mechanics | 2.C2 |
| Ungermann, Matthias | Do Hessian high schools foster understanding of Nature of Science? | 2.G3 |
| Vignal, Michael | Comparing Unprompted and Prompted Student-Generated Diagrams | 2.L5 |
| Walsh, Cole | Connecting the dots: Student social networks in introductory physics labs | 2.F2 |
| Walter, Paul J. | Comparing item response curves of matched pre-/post-FCI respondents | 2.F4 |
| Waterson, Alyssa C. | Analyzing time-to-degree for transfer students at a Large Midwestern University | 2.J3 |
| Weidner, Carrie A. | Investigating student use of a flexible tool for simulating and visualizing quantum mechanics | 2.K4 |
| Williams, Stephanie M | Living Physics Portal: Designing analytics to map faculty's evolving participation | 2.E4 |
| Zich, Raymond | Changes to equipotential diagrams to improve student ranking of electric potential | 2.L2 |
| Zwartz, Michael | Examining student growth in laboratory notebook practices in introductory physics courses | 2.D3 |

**Poster Session III**
**Thursday, July 23, 2:00pm EDT**

**Underline Conferences**

| | | |
|---|---|---|
| Archibeque, Benjamin | Analyzing discussions of under-representation in a high school classroom | 3.G4 |
| Arielle, Acacia | Student ownership of lab projects: evolution across temporal project phases | 3.D3 |
| Bauman, Lauren C. | Identifying student conceptual resources for understanding electric current | 3.I2 |
| Bender, Lydia G | How Faculty Take Up Ideas from a Professional Development Program | 3.E3 |
| Bennett, Michael B. | Toward a Comprehensive Characterization of Pedagogy in Informal Physics Learning Spaces | 3.B4 |
| Boudreaux, Andrew | Toward a framework for the natures of proportional reasoning in introductory physics | 3.J5 |
| Broadfoot, Cheyenne | Identifying student resources for understanding kinematics | 3.I5 |
| Bugge, Danielle | The long-term effects of learning in an ISLE approach classroom | 3.J1 |
| Canright, Jared | Leveraging virtual reality for student development of force models in the introductory lab | 3.D2 |
| Cao, Ying | Emergent Explicit Group Regulation in Scientific Inquiry | 3.G3 |
| Christman, Elaine | Exploring the CLASS with Item Response Theory | 3.M3 |
| Conlin, Luke | From 'having a day' to doing astronomy: Supporting families learning together | 3.B2 |
| Crossette, Nate | Investigating how graduate students connect microstates and macrostates with entropy | 3.K2 |
| DeStefano, Paul | Rapid creation and assessment of introductory physics laboratory curriculum for distance-learning | 3.F3 |
| Dopatka, Liza | Measuring students' interest in physics | 3.A4 |
| Fairfield, Jessamyn | Bright Club: Using Stand-up Comedy for Informal Education | 3.B1 |
| Flowers, Abigail | Development of computational thinking skills in an introductory physics lab. | 3.H2 |
| Fox, Michael | Capturing modeling pathways using the Modeling Assessment for Physics Laboratory Experiments | 3.C5 |
| Franklin, Scott | Who Goes where: patterns in academic field switching of successful college graduates | 3.A1 |
| Fung, Anderson T. | Ordinary differential equations in physics: some preliminary observations of the role of rote procedure | 3.K4 |
| Gavrin, Andrew D. | Physics students' reactions to an abrupt shift in instruction during the COVID-19 pandemic | 3.G5 |
| Gifford, Julian D. | A framework for curriculum design to support mathematical sense making | 3.M5 |
| Giordano, Nicholas | Developing Augmented Reality Modules to Teach Electromagnetism | 3.I4 |
| Goodhew, Lisa | A case of resources-oriented instruction in calculus-based introductory physics | 3.J3 |
| Hamdan, Alia | Contributing Effects to Students' Performance on the FCI as a Measure of Physics Knowledge | 3.L3 |
| Henderson, Rachel | Implementing a mixed-methods approach to understand students' self-efficacy: | 3.F2 |

| | | |
|---|---|---|
| | A pilot study | |
| Hertel, Matthew E | A graduate teaching assistant's approach to building a supportive learning community for introductory physics students. | 3.E4 |
| Hoehn, Jessica R. | Investigating students' views about the role of writing in physics lab classes | 3.D5 |
| Holmes, Natasha | Preliminary evidence for available roles in mixed-gender and all-women lab groups | 3.F1 |
| Huffman, James | Investigating Upper-Division Students' Interpretations of the Divergence Theorem | 3.K1 |
| Ives, Joss | Exploratory Factor Analysis of a survey on group-exam experiences and subsequent investigation of the role of group familiarity | 3.F4 |
| Justice, Paul | Instructional Pragmatism: Using a Variety of Evidence-Based Approaches Flexibly to Improve Student Learning | 3.L1 |
| Kamenetzky, Julia | Using Student-Generated Reading Questions to Encourage Pre-Class Preparation in Introductory Physics | 3.K5 |
| Logan, Savannah L. | College faculty support for grade 7-12 teaching careers: survey results and comparisons to student perceptions | 3.E5 |
| May, Jason M. | Students' dynamic engagement with experimental data in a physics laboratory setting | 3.D4 |
| McInerny, Alistair | Investigating a collaborative group exam as an instructional tool to address student reasoning difficulties that remain even after instruction | 3.L4 |
| McQuade, Alexa | Characteristics of institutions with Learning Assistant programs: An equity investigation | 3.E6 |
| Mullen, Claire | A Community of Practice Approach to Identity Formation | 3.A2 |
| Muller, Alexandria | Design Principles to Support Physics and Engineering Learning in Complementary Classrooms and Field Trip Activities | 3.B3 |
| Myers, Carissa | Student perspective about the impacts of feedback | 3.G1 |
| Okwei, Eugene | Understanding the Impact of Large-Scale Radio Astronomy Projects on Student Engagement With Physics in Ghana | 3.H4 |
| Oliver, Kristin | Examining effective mentorship in undergraduate research experiences at a large research institution | 3.F5 |
| Olsho, Alexis | Online administration of a reasoning inventory in development | 3.C2 |
| Owens, Lindsay M. | Physics GRE Requirements Create Uneven Playing Field for Graduate Applicants | 3.A5 |
| Pawlak, Alanna | Improving education through departmental change: a comparison of approaches | 3.E2 |
| Pugh, Samantha | Developing Business Acumen and Employability in Physics Undergraduates: What do students really learn? | 3.M2 |
| Quaal, Adam | Exploratory factor analysis of the QMCA | 3.C4 |
| Riihiluoma, William | Student Use of Dirac Notation to Express Probability Concepts in Quantum Mechanics | 3.K3 |
| Salmani, Fatema Al | A Rubric for Assessing Thinking Skills in Free-Response Exam Problems | 3.C1 |
| Scherr, Rachel E | Centering and marginalization in introductory university physics courses | 3.J4 |

| | | |
|---|---|---|
| Smith, Trevor | Toward a valid instrument for measuring physics quantitative literacy | 3.I3 |
| Stanley, Bryan | Perspectives on informal programs: How site visits can help us learn more | 3.B5 |
| Stewart, John | What does the Force and Motion Conceptual Evaluation pretest measure? | 3.C3 |
| Sulaiman, Nidhal | Impact on students' views of experimental physics from a large introductory physics lab course | 3.D1 |
| Tipton, Maya | Does IPLS help students apply physics to biology? | 3.M1 |
| Traxler, Adrienne | Chili and mistakes: Students reflect on research | 3.H5 |
| Wang, Jianlan | Scrutinize SA-student interaction in inquiry-oriented college physics courses | 3.E1 |
| Weller, Daniel P. | Video Analysis of Variation in Computational Thinking Practices in Physics | 3.H1 |
| Werth, Alexandra | Process of transforming of an introductory mechanics lab course at Fort Lewis College | 3.L2 |
| Whitcomb, Kyle | Recognition always matters: A cross-sectional study of the physics identity of physics majors | 3.A3 |
| Wilcox, Bethany | Understanding the student experience with emergency remote teaching | 3.G2 |
| Wilson, Michael B | E&M Plane Wave Visualization Designed for Improved Student Understanding | 3.I1 |
| Winther-Larsen, Sebastian Gregorius | Quantifying professors' effect on student grades | 3.M4 |
| Young, Tamara | A case of successful learning about magnetism through the use of evidence | 3.J2 |

## Thursday, July 23, 10:00am EDT
## Parallel Session Cluster I: Talk Symposium

### Establishing scientific norms in the lab: a spotlight on the instructor

**Smadar Levy and Edit Yerushalmi, Weizmann Institute of Science**
**Co-authors: Russell Clark, Danny Doucette, Dimitri R. Dounas-Frazer, Eugenia Etkina, Dorothy Langley, Esther Magen, Joshua Rutberg, Chandralekha Singh, Zehorit Kapach**

Educators interested in changing the norms of the instructional physics lab to better reflect experimental research practices face a tricky challenge: on the one hand, it is the instructors' responsibility to establish the desirable classroom norms; on the other hand, the instructors themselves must undergo a process of change, as their habits and expectations are constructed within former experiences that may hinder the introduction of new norms. To alter classroom norms, instructors need to engage in a profound learning process, where they change their views and knowledge in the very process of applying new classroom practice. This session will focus on professional development of lab instructors while implementing new classroom practices. It will encompass studies conducted in various contexts in terms of: A. the extent of the investigation, spanning from short instructional labs to multi-week projects; B. the stage in the learning continuum – high-school physics, introductory physics and upper-division labs.

---

Symposium Talk 1

### Making lab TA professional development work (and some evidence that it does)

**Primary Contact: Danny Doucette, University of Pittsburgh**
**Co-authors: Chandralekha Singh, University of Pittsburgh; Russell Clark, University of Pittsburgh**

At large universities, where introductory physics labs are often run by graduate student teaching assistants (TAs), it may be necessary to provide professional development for TAs in order to successfully implement inquiry-based lab learning, establish TA practices that support inclusive education in the lab, or effectively introduce other important lab practices. As part of a transformation of our introductory physics labs toward an inquiry-based model, we developed and implemented a research-based training program that includes relevant activities and role-playing while attempting to account for TA `buy-in'. Our analysis demonstrates a positive shift in TA views about student learning and an encouraging improvement in instructional behaviors for TAs who participated in our lab TA professional development program. We have also worked to build systems to both sustain and disseminate our lab TA professional development program and will briefly share some of these efforts.

---

Symposium Talk 2

### Professional development and struggles of beginning instructors teaching design labs

**Primary Contact: Joshua Rutberg, Rutgers University**
**Co-authors: Eugenia Etkina**

Being a teacher in an instructional laboratory where students design their own experiments is not an easy task. Being a first year graduate TA who never taught before makes this challenge even harder. How do you guide the students to design a productive experiment? How do you teach them to

communicate their findings? How do you create a learning community in your classroom? We will report on our work in an urban university where we implemented the Investigative Learning Environment (ISLE) approach in a large-enrollment introductory physics sequence (algebra and calculus based). A part of the approach involves students designing their own experiments in labs guided by specific questions and self-assessment rubrics. We describe professional development efforts, data collection (observation protocols) and their effects on the instruction and student learning and attitudes.

---

Symposium Talk 3

## Re-defining lab norms via professional learning communities of physics teachers

**Primary Contact: Smadar Levy, Weizmann Institute of Science**
**Co-authors: Zehorit Kapach, Esther Magen, Edit Yerushalmi**

We present a study of a large-scale intervention designed to shift lab instruction away from tightly prescribed lab norms. The intervention was implemented in a network of Professional Learning Communities of Israeli high-school physics teachers (N=250) operating in a high-stakes exam setting with limited resources, and catering to diverse groups of students. An introductory questionnaire examined the lab goals that the teachers valued, revealing a gap between teachers' optimal lab goals and prevailing ones, in particular as concerns experimental design. The intervention addressed both teachers' interest in change as well as the constraints imposed by the setting in which they work, by: a) modest restructuring of traditional labs: encouraging students to reflect on the considerations underlying the experimental design; b) involving teachers in collaborative reflection on classroom enactments of the restructured labs. Indeed, most teachers chose to carry out the restructured labs. We will describe barriers and affordances that the teachers identified when reflecting on their experience.

---

Symposium Talk 4

## Taxonomy of teaching practices during group projects in lab courses

**Primary Contact: Dimitri R. Dounas-Frazer, Western Washington University**

Compared to other formal learning environments in undergraduate physics programs, multiweek group projects in lab courses give rise to unique interactions between students, their peers, their instructors, and apparatus. What does teaching look like in these contexts? How do instructors change their teaching practices as students transition from proposing project topics to carrying out experiments and reporting on results? To answer these and related questions, we conducted a multiple case study of group project implementations in upper-division labs at five universities. In this presentation, we draw on data from interviews and surveys with instructors and students to identify a variety of teaching practices. We further describe the intended purposes and perceived impacts of these practices. Preliminary data analysis suggests that group projects may be a shared endeavor in which students and instructors have asymmetric apprenticeship-style roles and responsibilities.

---

Symposium Talk 5

## Training teachers as physics research mentors: four personal development stories

**Primary Contact: Dorothy Langley, Holon Institute of Technology**
**Co-authors: Edit Yerushalmi**

The Research Physics program, launched in 2016, offers Israeli high school physics majors extra credit for performing a research project guided by teacher-mentors. The 240 hour Research Physics Mentors' training program is designed as a fast-track framework taking novice teacher-mentors through a professional development process within a community of experts and peers. The practical component involves mentoring a student-pair for 18 months, from topic selection until the final exam. The program is based on a "structuring and problematizing" scaffolding process (Reiser, 2004), enabling the development and application of knowledge, skills, beliefs and attitudes. During 2017-2019 a qualitative study, sketched profiles of four trainee teachers' professional development, describing how they maintained a viable mentoring process with their unique student team and research topic. The analysis of multiple evidence resources tracked issues of mentoring responsibility and scientific and mentoring knowledge, relating them to assignments and interactions with program leaders, students and peers.

## Thursday, July 23, 10:00am EDT
## Parallel Session Cluster I: Custom Format

### Expanding your network: IPER Community buildathon

**Claudia Fracchiolla, University College Dublin**
**Co-authors: Kathleen Hinko and Brean Prefontaine - Michigan State University**

With the new format for PERC and the unprecedented times that we are all living in, we wanted to ensure that there was a space for the informal physics community to talk about both wins and concerns the community is facing. In this live virtual session, we are interested in strengthening and growing the Informal Physics Education Research (IPER) community in order to offer support to our fellow informal practitioners and researchers. We hope to have a discussion based session where we can touch on issues related to budgets, moving to virtual programming, creating new content, applying for funding, program futures, and many more challenges that will be faced. Additionally, we would love to use our collective knowledge to crowdsource ways to combat these issues and to move forward with advocating for the relevancy of informal education in a post-pandemic society. These issues are relevant now for everyone in our community and we are interested in hearing all voices and perspectives during this session.

## Thursday, July 23, 10:00am EDT
## Parallel Session Cluster I: Juried Talk Session

**Juried Talks I**

**PERC Organizing Committee**

---

Juried Talk 1

### Constructing particle-level models to promote macro-level conceptualization of electric circuits in middle school

**Primary Contact: Elon Langbeheim, Ben-Gurion University of the Negev**
**Co-authors: Janan Saba and Sharona, T Levy, University of Haifa, Israel**

Electricity is the main form of energy transfer and use in the 21st century, and its understanding is of central importance. We describe how 8th grade students learn the physics of electric circuits through building computational particle models of conductors. The gradual construction of the computational particle model of the conductor, embodies the conceptualization of repulsion between free electrons, the push of the electric field, and the hindrance of the stationary ions. Comparing Pre/Post questionnaire data with a control group, shows that building the model is a sound basis for macro-level understanding of electric dynamics. Qualitative analyses highlight how creative activities such as drawing the conductor's boundary and spreading electrons in it, complement observing the working model and discussing its' mechanism in the classroom. Drawing on constructivist and grounded theories of learning, we discuss how constructing models and making conceptual micro-macro connections results in meaningful learning of this difficult topic.

---

Juried Talk 2

### Game-based learning as a tool for promoting conceptual change in astronomy

**Primary Contact: Adriana Cardinot, National University of Ireland Galway**
**Co-authors: Jessamyn Fairfield, National University of Ireland Galway**

Game-based learning (GBL) has garnered much attention among researchers, as games could be an essential tool in the science classroom to enhance the learning process through play. However, the inclusion of games in astronomy education has been hampered by the lack of astronomy game resources validated in the classroom and aligned with curriculum learning outcomes. This study investigated the use of GBL activities in secondary students' conceptual understanding of astronomical concepts from the curriculum. A quasi-experimental research study involved 483 students from junior-cycle level (12-16 years) in Ireland. In this study, it was observed that the sociocultural environment promoted by the games favours student's motivation and prolonged conceptual change. During this presentation, the authors will report on how GBL facilitated or constrained the student learning process. Particularly, we will focus on how the ontological aspects of students' reasoning about astronomical phenomena are affected by GBL instruction.

---

Juried Talk 3

## Providing learning opportunities based on cognitive psychology and PER: student adoption, attitudes, and results in introductory mechanics

**Primary Contact: Vegard Gjerde, University of Bergen**
**Co-authors: Bodil Holst and Stein Dankert Kolstø**

A considerable amount of physics education research has been dedicated to conceptual understanding, misconceptions and problem-solving. However, as recently pointed by Zu, Munsell, and Rebello (2019), there is only a limited amount of research on more basic cognitive processes, such as the use of retrieval practice for improved memory. To address this literature gap, we provided a broad array of learning opportunities to students in an introductory mechanics course, with the intent to support both basic and complex learning processes. The learning strategies were: i) retrieval practice for memory strength of basic physics facts, ii) elaborative encoding for building initial associative links, iii) self-explanation for building abstract declarative rules for problem-solving, and iv) peer instruction for conceptual understanding. We present here an overview of the results of this investigation, some of which have already been accepted for publication, for example that weaker students seem to benefit more from retrieval practice.

---

Juried Talk 4

## Qualitative analysis of students' perceptions of their self-efficacy in a flipped integral calculus course

**Primary Contact: Jillian Mellen, Rutgers University, New Brunswick**
**Co-authors: Geraldine L. Cochran, John Kerrigan, Lydia Prendergast, Antonio Silva - Rutgers University, New Brunswick**

Students' perceptions of their confidence in their ability to complete a task, known as self-efficacy, affects student effort and persistence. Self-efficacy increases with improvements in learning methods and is a good predictor for success. Classroom dynamics also impact students' self-efficacy by allowing for different sources of self-efficacy. Previous research indicates that self-efficacy is context-specific and that male and female students benefit from different sources of self-efficacy. In this study, we analyzed interviews from 12 students enrolled in a flipped integral calculus course to understand their perceptions of self-efficacy and how these perceptions impact their learning experiences. Findings reveal that experiences in previous math courses, particularly high school, impacted students' perceptions of their self-efficacy in math both positively and negatively, active learning increased students' confidence in their ability to do math from their perspective, and verbal persuasion (implicit encouragement) increased students' confidence and was seen as a helpful way to learn.

## Thursday, July 23, 10:00am EDT
## Parallel Session Cluster I: Talk Symposium

### Recent results on the classroom effectiveness of Virtual Reality and Augmented Reality technology

### Chris Orban, Ohio State University

Each year brings improvements to the quality and availability of commercial virtual reality and so-called "augmented" reality devices. These devices represent a great leap in our ability to convey abstract concepts like electric and magnetic fields as well as other ideas. From a physics education research perspective, we have only begun to explore the impact that this could have on instruction. Interestingly, some studies find that these visualizations do not outperform other, more traditional methods for visualization like watching a video on a conventional computer monitor. In this session we showcase recent results from four different scholars. Each scholar will provide a 15 minute overview and at the end participants will be able to experience the visualizations and discuss the future of the field. In 2019 when this session was held, not all presenters had student data to report but this year all presenters have student data to share.

---

Symposium Talk 1

### Design and student experience of novel physics systems delivered in virtual reality labs

**Primary Contact: Jared Canright, University of Washington**

The University of Washington (UW) Physics Education Group is creating virtual reality (VR) lab environments that simulate "novel" physical phenomena that do not exist in the real world but follow laws that can be modeled using techniques accessible to first-year physics laboratory students. Presenting these novel phenomena in VR provides an opportunity for authentic model-generating activities in introductory labs while retaining key components of in-person labs such as hands-on interaction, measurement uncertainty, and opportunities to build teamwork skills. This talk describes in detail the development of and students' experience modeling one such novel phenomenon, identifying the scientific reasoning skills students bring to bear in the absence of any expected experimental outcome and highlighting opportunities for this technique to build those skills.

---

Symposium Talk 2

### Teaching Force and Motion in Augmented Reality

**Primary Contact: David Rosengrant, University of South Florida St. Petersburg**

Technology has always been a medium to help teachers provide the best educational experiences for our nation's youth. Augmented and Virtual Reality is becoming more common in the classroom which brings unprecedented opportunities. Our team created an Augmented Reality (AR) application to use with the Merge Cube that focuses on Forces and Motion. This application is used with multiple in-service and pre-service teachers for two reasons. The first is to enhance their understanding of mechanics. The second is that they allow us to asses both the usability and willingness to use not only

that application, but ARVR in general. We found that after modifications they were extremely receptive to the application, learned from it and would implement it in the future.

---

Symposium Talk 3

## Using Virtual Reality in Electrostatics Instruction: The Impact of Training

**Primary Contact: Chris Porter, The Ohio State University**

As VR becomes more common, there remain unanswered questions regarding how best to use this technology in the classroom. On the topic of electrostatics, for example, a large, controlled, randomized study performed by Smith et al. (2017), found that VR-based instruction had an overall negligible impact on student learning compared to videos or images. However, they did find a strong trend for students who reported frequent video game play to learn better from VR than other media. One possible interpretation of this result is that videogame play provides a kind of "training" that enables a student to learn more comfortably in the virtual environment. In the present work we test if a VR training activity unrelated to electrostatics can help prepare students to learn electrostatics from subsequent VR instruction. We find that preliminary VR training leads to a small but statistically significant improvement in student performance on our electrostatics assessment.

---

Symposium Talk 4

## Vignettes on VR Learning Applications: 2D vs. 3D, and "Aha!" Moments in Collaborative Learning

**Primary Contact: Scott Greenwald, Massachusetts Institute of Technology**

The use of immersive interactive virtual environments has long been investigated as an approach to teaching physics concepts. Rigorous demonstrations of its learning value have proven elusive, although insights continue to be gained. This presentation will cover one comparative study and one exploratory study in this area. In the first, a set of activities are learned in either 2D or VR, and students' performance is tested in 2D. Quantitative and qualitative feedback provided insights into the benefits of VR for complex spatial topics, including a set of design guidelines. In the second study, pairs and small groups of students watch immersive mini-lectures in a shared virtual environment and are given opportunities to collaboratively interact with the content. A behavioral coding approach revealed characteristics of collaborative interactions that led to "Aha!" moments.

## Thursday, July 23, 10:00am EDT
## Parallel Session Cluster I: Poster Symposium

### Students' Understanding of Fluids

**Dawn Meredith, University of New Hampshire**
**Co-authors: Rebecca Lindell and Rebecca Rosenblatt, Tiliadal STEM Education: Solutions for Higher Education**

An understanding of static and dynamics fluids principles is essential for life students, as these principles constrain and enable life. Continuity, for example, dictates that flow slows down in capillaries since the total cross-sectional area is much larger than the aorta. This allows the slow, essential process of diffusion to take place. To improve the teaching and learning of fluids in introductory courses (particularly IPLS), the research presented here describe several different approaches to elucidate, measure, and support students' understanding of fluids concepts.

---

Symposium Poster 1

### Proposed Development Methodology for the Fluid Conceptual Evaluation (FCE)

**Primary Contact: Rebecca Lindell, Tiliadal STEM Education: Solutions for Higher Education**

Since the call to action in 2003, many physicists and physics education researchers have dedicated their efforts into the reform of the Introductory Physics Life Science majors (IPLS) course. Life science and Health care experts strongly encourage IPLS instructors to cover some topics in more depth: fluids, diffusion, osmosis, entropy, enthalpy, and electrostatic forces at the microscopic level. Our research team has focused our efforts to improving IPLS students' understanding of fluids. My role has been to use my expertise in Research-Based Conceptual Assessment Instruments (RbCLAI) development, to develop a methodology for the development of the Fluids Conceptual Evaluation (FCE), an evaluation instrument designed to assess IPLS students' understanding of fluids statics and dynamics. In this poster, I will discuss the different considerations that went into this development methodology, specifically the roles of psychometrics and Rasch analysis.

---

Symposium Poster 2

### Scaffolding student mechanistic reasoning about static and dynamic liquids

**Primary Contact: Dawn Meredith, University of New Hampshire**

The kinetic theory of gases provides a powerful set of mechanistic resources that allows students to reason productively about pressure in gases. We give evidence students (and experts) are lacking similar resources for reasoning about liquids (especially water in an Introductory Physics for Life Science course) and provide initial evidence of some possibly productive resources.

---

Symposium Poster 3

## Visual Attention and Affordance Lenses for: Understanding Student Diagram Use and Designing Improved Instruction of Fluid Dynamics in a Physics for Li

**Primary Contact: Rebecca Rosenblatt, Tiliadal STEM Education: Solutions for Higher Education**

Diagrams are ubiquitous in STEM. These diagrams vary from problem solving tools (like force diagrams) to ways to visualize information and concepts (like a cell diagram or ATP cycle) or understand an equation or data set (like graphs). I will describe the two theories - affordance and visual attention – and I will present several cases from the literature and my own research showing how these theories are lenses for understanding student difficulties with diagrams. In addition, I will present data from a set of experiments my group has done that examines prior student knowledge and its effect on diagram use and visual attention within images of fluid flow through pipes. This data illustrates that, while current STEM diagrams have a lot of room for improvement as instructional tools, designing improvements for these diagrams will be complex.

## Thursday, July 23, 10:00am EDT
## Parallel Session Cluster I: Custom Format

### What was, is and will be Physics Education Research

**Ramon Barthelemy, University of Utah**
**Co-authors: Alexis Knaub, Valeria Otero, Brian Zamarripa, Ida Rodriguez**

Physics Education Research has been a new and important part of the physics and education landscape for over forty years. The field has evolved significantly since the introduction of research articles in the American Journal of Physics, the creation of Phys Rev PER, and the start of PERC in 1997. This session will facilitate a discussion with invited speakers and the audience to discuss the past, present, and future of the field of PER.

## Thursday, July 23, 12:00pm EDT
## Parallel Session Cluster II: Custom Format

### Diverse Career Paths in Physics Education: A Panel Discussion

**Rachel Henderson, Department of Physics & Astronomy, Michigan State University**
**Co-authors: Alanna Pawlak, Center for STEM Learning, University of Colorado Boulder; Tom Finzell, Department of Physics & Astronomy, Macalester College**

Experience and training in physics education research and physics teaching prepare individuals for a variety of careers. However, despite the versatility of physics education training, "traditional" career paths including research-focused post-doctoral positions leading to tenure track positions at universities are often implicitly or explicitly emphasized. To provide the physics education research community, particularly members of the community who are early in their careers, with a more complete picture of the landscape of potential careers, this session will provide a space to discuss experiences in a variety of physics education careers. The panelists in this session will include physicists from industry, community colleges, data science, consulting both in and outside of academia, and positions within the American Physical Society. The panel discussion will begin with each panelist describing their backgrounds and current positions, followed by an open question and answer format between the panel and the audience.

## Thursday, July 23, 12:00pm EDT
## Parallel Session Cluster II: Talk Symposium

### Evaluation of Innovative Reforms in Upper Division Physics Courses

### Rebecca Lindell, Tiliadal STEM Education: Solutions for Higher Education

Based on the successful reforms of introductory physics courses by Physics Education Researchers (PERers), physics educators and education researchers are now interested in making similar reforms to their upper-division courses. Unlike prior reform efforts in introductory physics courses, driving these reforms are the needs of the Department and not necessarily individual research interests. Many of these upper level reforms occur outside the direction of PERers and thus may not have robust evaluation plans. This does not mean that these innovations are not working, but rather that different evaluation methods must become available. In this session, the four speakers will discuss their innovations to upper-level physics courses and the methods that they have undertaken to evaluate the success of their innovations.

---

Symposium Talk 1

### Introducing Computational Physics Across the Curriculum

**Primary Contact: A.Gavrin, Indiana University Purdue University Indianapolis**
**Co-authors: Gautam Vemuri and Yogesh Joglekar, Indiana University Purdue University Indianapolis**

Our department has undertaken a multi-year effort to make computational methods central to our physics curriculum. Our students should graduate with the attitude that computational approaches are a normal part of physics, used every day, and for a multitude of tasks. To accomplish this, our current objective is to make 25% of all work done by students in our upper division courses computational. This talk will begin with an overview of the history and change process of this initiative. What lead us to this decision, and how we have chosen to implement it as a department. It will then present an instrument developed in-house to measure students' attitudes and self-efficacy with respect to computation. This discussion will include both the process by which the instrument was developed, and what we have learned from the first few semesters of data. IUPUI is an urban public institution graduating 10-15 majors each year.

---

Symposium Talk 2

### Modernizing Upper-Division Mechanics: Preparing Students for a Complex World

**Primary Contact: David D. Nolte, Purdue University**

Given the growing importance of dynamical systems in science and technology, it is important to give students an up-to-date foundation for their future careers, embedding topics of modern dynamics--chaos, synchronization, network theory, neural networks, evolutionary change, econophysics and general relativity--within the context of traditional physics founded on Lagrangian and Hamiltonian physics. The goal of this approach is to modernize the teaching of junior-level dynamics, responsive to a changing society, while retaining the core traditions and common language of dynamics texts. The modern perspective is based on geometric aspects of dynamics and state space, providing a unifying

context and environment for learning. The class and textbook using this approach has been pursued for the last 5 years at Purdue University, providing case studies in student reception of this method.

---

Symposium Talk 3

## Skill Development in Physics Labs Beyond the First Year

**Primary Contact: Joseph F. Kozminski, Lewis University**

The recent AAPT recommendations on the laboratory curriculum and on computational physics, as well as the Phys 21 report from the APS and AAPT Joint Task Force on Undergraduate Physics Programs, encourage physics programs to prepare students for a range of opportunities after graduation through a curriculum that develops and reinforces of a set of transferrable skills and knowledge. The laboratory is an ideal venue for developing many of the skills discussed in these documents, including design, technical, analytical, and communication skills. This talk will address innovative ways to implement these recommendations throughout the upper level laboratory curriculum, examples of revised curricula from Lewis University and other institutions, methods of evaluating skill development in the lab, and opportunities for developing new assessments.

---

Symposium Talk 4

## Team-based Learning in Upper-Level Physics Courses: A Qualitative Case Study

**Primary Contact: Michele McColgan, Sienna College**

Developed by Larry Michaelson, a management professor at the University of Oklahoma, Team-based learning (TBL) details a pedagogical approach designed to improve learning outcomes, increase student engagement, and create a sense of community. Unlike group-work used in other fields this approach explicitly has several key elements: teams of 5-7 students stay together for the entire semester, teams participate in a Readiness Assurance Process and in-class team activities, individual team members evaluate their members' contributions, and course grade weighting includes team components. After attending a workshop led by the Council on Teaching and Learning in 2017, four professors at Siena College in upstate NY began incorporating this pedagogy into their physics courses at all levels. In this talk, I will describe team-based learning in upper-level physics classrooms at Siena College. To evaluate this innovation, we are conducting a series of qualitative case studies of student experience of team-based learning in our upper-division physics courses. The implementation of team-based learning in physics courses and a preliminary report of the qualitative analysis will be described.

## Thursday, July 23, 12:00pm EDT
## Parallel Session Cluster II: Talk Symposium

### Future directions in PER: Reflecting critically on student success

**Dimitri R. Dounas-Frazer, Western Washington University**
**Co-authors: L. Trenton S. Marsh, Brian Zamarripa Roman, and Jacquelyn J. Chini, University of Central Florida; Chandra Turpen and Fidel Amezcua, University of Maryland; Gina Quan, San Jose State University.**

For about four decades, physics education researchers have engaged in development of theories, pedagogies, and assessments to support physics learners to be successful. PER literature includes many conceptions of "success": gains on concept inventories, expert-like beliefs about physics, retention in physics education and career pathways, etc. However, these conceptions are often defined by researchers and informed by institutional priorities or federal mandates. Rarely is success defined by students themselves, especially students of color or others minoritized in the physical sciences. Physics learners begin conceptualizing success at a young age, and their ideas about what it means to be successful are informed by opportunities to make meaning of success in their K-12 education. In this session, speakers reveal how students "(re)imagine success" (Marsh, 2018) through students' own priorities, relationships, and ethics. In doing so, we envision a future in which students' values and voices play larger roles in research agendas.

---

Symposium Talk 1

### (Re)imagining Success Through Photovoice At a High-Achieving Urban Charter School

**Primary Contact: L. Trenton S. Marsh, University of Central Florida**

The talk highlights photovoice, a participatory method that gives power to creators of images to capture experiences that are central to their life. Black and Latinx students' verbal considerations of success in the context of their urban charter school is included, as is a sample of students' visual data about what success is outside of their schooling context. The study reveals the school's "no-excuses" orientation to teaching and learning fosters an oppressive definition of success in the context of classrooms. However, photovoice reveals students are able to resist the limited view as four emergent findings reveal how students (re)imagine success. Lastly, implications about what educators and school communities may learn, if students were seen as active co-constructors in the design and implementation of their own education is discussed.

---

Symposium Talk 2

### Explicating the goal contents of Latinx female physics students

**Primary Contact: Brian Zamarripa Roman, University of Central Florida**
**Co-authors: Jacquelyn J. Chini, University of Central Florida**

Latinas in physics experience multiple marginalization due to the intersection of their ethnicity and gender, thus it is important for the physics community to focus support and help them achieve their success in physics. To begin supporting Latinas in achieving success it is crucial that the community has

an understanding of the diversity of goals that contribute to their overall success in physics. With this qualitative study we used interviews to explore the goals expressed by 20 undergraduate and graduate students who identify as Latinas across the United States. Guided by Motivational Systems Theory, we present the goals participants had in common (e.g. resource provisions and social responsibilities) as well as the different goals they emphasized (e.g. emphasis on affective goals versus integrative social relationship goals). These goal contents provide a more nuanced level of detail to goal orientations held by Latinas in physics and serve as examples of the relevant goals that the physics community should support.

---

Symposium Talk 3

## Students' exploring and refining their equity ethic within the Access Network

**Primary Contact: Gina M. Quan, San José State University**
**Co-authors: Chandra A. Turpen, University of Maryland College Park; Fidel Amezcua, Georgia Institute of Technology**

The Access Network is an organization that supports vibrant interactions among students and faculty who advocate for equity work in the physical sciences. This paper uses McGee and Bentley's framework of "equity ethic" (EE) to understand how Access student leaders adopt and refine a commitment to equity and social justice work within the physical sciences. In McGee and Bentley's study of STEM students of color, they define EE as students' sense of altruism and collectivism within and outside of their communities. Through interviews with student leaders, we model components of students' EEs and how their EEs are influenced by their participation in Access. Student accounts illustrate that they are invested in improving equity within their disciplinary communities and see progress toward these goals as an important measure of success. Our findings highlight how students are already infusing an EE into their professional physics activities.

## Thursday, July 23, 12:00pm EDT
## Parallel Session Cluster II: Juried Talk Session

**Juried Talks II**

**PERC Organizing Committee**

---

Juried Talk 1

### Epistemological, socialization, and help seeking views in traditional and at-home undergraduate physics laboratories

**Primary Contact: Drew J. Rosen, Stony Brook University**
**Co-authors: Angela M. Kelly, Stony Brook University**

Undergraduate physics laboratory course structures have been identified in policy reports for novel design innovations to meet the needs of a diverse and growing student population. To this end, an at-home laboratory option was implemented at a large, public university for introductory physics students. A quasi-experimental, observational quantitative study was undertaken to understand students' epistemological views, socialization, and help seeking behaviors in in-person and at-home laboratory environments. Students in introductory physics (N=998) were surveyed to elicit their epistemological beliefs about physics laboratory work and their views on social engagement and academic help-seeking. Students showed no statistically significant differences in attitudes related to epistemological beliefs and help-seeking behaviors when compared to students in traditional laboratory courses. In-person students valued socialization higher than at-home students. This study provides insights into the feasibility of at-home, hands-on laboratory work to meet students' needs, and institutional recommendations for student advisement.

---

Juried Talk 2

### Painted yellow lines: Exploring parameters of physics teacher self-efficacy in a new teaching landscape

**Primary Contact: Richard Hechter, University of Manitoba**

New curricular outcomes are being developed and adopted towards emphasizing personal explanations from cultural experiences and influences intended to complement prevailing curriculum elements of physics phenomena and concepts. Efforts to educate for social justice, inclusion, and cultural awareness across disciplines is a departure from the siloed history of content only curricular matter. However, educating for global citizenship situates teachers in unchartered territory to include new perspectives and knowledge. This study, conducted with secondary level physics teachers (n=32), explored contributing factors related to their perceived efficacy of teaching in these new directions. Findings indicate that a) years of teaching, b) pedagogical strategies and foci, c) epistemological frames, and d) perceived degree of autonomy in conducting classes without administrative interference contribute to their perceptions. With the call for increased diversity in physics, this talk articulates implications for teaching physics in this modern educational landscape.

---

Juried Talk 3

## The impact of extra credit incentives on students' work habits when completing online homework assignments

**Primary Contact: Zachary Felker, University of Central Florida**
**Co-authors: Matthew W Guthrie and Zhongzhou Chen, University of Central Florida**

Instructors know that many college students tend to delay working on homework assignments until close to the due date. Such "cramming" behavior may lead to insufficient engagement with learning materials. In this study, we investigate the effectiveness of reducing "cramming" by offering small amounts of extra credit for completing parts of the assignments before the due date. Student learning behavior is characterized by first identifying clusters of clickstream records that represent a continuous study session, then analyzing the duration and starting time of each study session. We observed that after offering extra credit for early completion, the average duration of study sessions remains unchanged, but more study sessions took place earlier than the assignment due date, shortly before the extra credit due dates. We will discuss how extra credit impacts different student populations, as well as the quality of students' learning behavior. As institutions across the nation shift abruptly to online learning at the onset of the COVID-19 epidemic, students are facing significant challenges to keep up with regular course schedules when studying from home, and due dates for online assignments must be more flexible as to accommodate for those challenges. This study suggests that the use of extra credit can be an effective method to incentivize completion of assignments among some students.

---

Juried Talk 4

## Transforming the Preparation of Physics GTAs

**Primary Contact: Emily Alicea-Munoz, School of Physics, Georgia Institute of Technology**
**Co-authors: Carol Subino Sullivan, Center for Teaching and Learning, Georgia Institute of Technology; Michael F. Schatz, School of Physics, Georgia Institute of Technology**

Graduate Teaching Assistants (GTAs) are key partners in the education of undergrads. Given the potentially large impact GTAs can have on undergraduate student learning, it is important to provide them with appropriate preparation for teaching. But GTAs are students themselves, and not all of them desire an academic career. Therefore, it is crucial that GTA preparation not be a burden but rather be fully integrated into their professional development. In this talk, we describe a GTA preparation course for first-year PhD students. Through a yearly cycle of implementation and revision, the course has evolved into a robust and comprehensive professional development program that is well-received by physics graduate students. We assessed the effectiveness of the course with a combination of surveys, pre/post tests, and student evaluations. We found that GTAs feel better prepared for teaching and adopt more learner-centered teaching approaches after participating in the program.

## Thursday, July 23, 12:00pm EDT
## Parallel Session Cluster II: Talk Symposium

### Using the theory of conceptual blending at the mathematics-physics interface

**John Thompson, University of Maine**

Throughout the physics curriculum, students learn and apply mathematics to model and reason about physical systems. Mathematics often serves as the structure for physics ideas. In the past two decades, several physics education researchers have adopted and adapted the conceptual blending framework to productively describe the ways students connect ideas from different conceptual spaces toward deeper content understanding. More recently, this framework has been applied to how students reason with and use mathematics in physics. This session will focus on the details of the theory behind conceptual blending and feature recent research using conceptual blending to describe the process of students combining mathematical and physical ideas while problem solving. Content level ranges from quantitative reasoning in introductory mechanics through vector differentials in intermediate electricity and magnetism to partial differential equations and boundary conditions in the context of heat conduction. This session will conclude with extended time for a deeper discussion of the theory of conceptual blending and questions for all speakers and participants. If time permits, we will discuss future options for applications of this framework in other research areas.

---

Symposium Talk 1

### A conceptual blend analysis of student reasoning about Physics Quantitative Literacy Reasoning Inventory (PIQL) items

**Primary Contact: Suzanne White Brahmia, University of Washington**
**Co-authors: Alexis Olsho, Charlotte Zimmermann, University of Washington; Trevor Smith, Rowan University**

Mathematical reasoning flexibility across physics contexts is a desirable learning outcome of introductory physics, where the "math world" and "physical world" intersect. Physics Quantitative Literacy (PQL) is a set of interconnected skills and habits of mind that support quantitative reasoning about the physical world, partially characterized by Sherin's symbolic forms. The Physics Inventory of Quantitative Literacy (PIQL) assesses student facility with the cognitive building blocks for creating symbolic models in physics -- proportional reasoning, co-variational reasoning, and reasoning with signed physics quantities. We apply a conceptual blending theory (CBT) analysis of interviews in which students think-aloud as they answer PIQL items. A CBT analysis helps uncover hierarchical, partially-correct reasoning patterns. CBT holds potential as a framework for mapping the emergence of mathematical reasoning flexibility in the introductory physics sequence that leads to productive reasoning, as characterized by Sherin's symbolic forms.

---

Symposium Talk 2

## Dynamic conceptual blending analysis to model student reasoning processes while integrating mathematics and physics

**Primary Contact: Sofie van den Eynde, Katholieke Universiteit Leuven**
**Co-authors: Benjamin P. Schermerhorn, California State University Fullerton; Johan Deprez and Mieke De Cock, KU Leuven; Martin Goedhart, University of Groningen; John R. Thompson, University of Maine**

Conceptual blending has been used to study student reasoning at the math-physics interface, but the current emphasis is mostly on the product of student reasoning, while information about the reasoning process is missing in the analysis. Therefore, we adapted the blending diagrams to also include the dynamics of student reasoning. In this session, we will use data from an interview study that focused on undergraduate students' understanding of boundary conditions for the heat equation. We demonstrate the construction of a dynamic blending diagram (DBD) and its use as an analytical framework. We show that by using a DBD, we can judge the degree to which students integrate their understanding of mathematics and physics. The DBD also enables the reader to follow the line of reasoning of the students. Moreover, a DBD can be used to diagnose difficulties in student reasoning.

---

Symposium Talk 3

## Modeling the construction and interpretation of equations: Incorporating symbolic forms into a conceptual blend

**Primary Contact: Benjamin P. Schermerhorn, California State University Fullerton**
**Co-authors: John R. Thompson, University of Maine**

Much of physics involves the construction and interpretation of equations. Sherin designed the symbolic forms analysis to describe students' construction of equations in physics. A symbolic form includes two components: the symbol template to represent the externalized structures of the equation and the conceptual schema to represent the acontextual mathematical justification of the symbol template. We incorporate symbolic forms into a conceptual blending framework to describe the ways in which construct and understand equations. Our model treats the conceptual schema as the underlying generic space of conceptual blending that frames the combination of the contextual information and the symbolic structure. We present this model in the context of student construction of non-Cartesian differential length vectors. We illustrate the affordances of the model by drawing further connections between the frameworks and expanding this approach to other contexts within our research.

## Thursday, July 23, 1:00pm EDT
## Parallel Session Cluster III: Talk Symposium

### All things Get the Facts Out: Perceptions, emotionally compelling messages, and data mining

**Brian Pyper, Brigham Young University - Idaho**
**Co-authors: Savannah L. Logan and Wendy K. Adams, Colorado School of Mines; Drew Isola, American Association of Physics Teachers**

The Get the Facts Out (GFO) project is a joint effort between four national societies and education researchers to change the conversation around grade 7-12 physics, chemistry, and math teaching careers. To develop recruitment materials and better understand best practices around recruiting math and science teachers, GFO has a rigorous research arm. This includes the study of both students', and faculty's perceptions of the teaching profession including development of instruments to measure these. We also have found it necessary to embark on a study of emotionally engaging ways to share facts about the profession as well as engaging in extensive data mining to assist with faculty buy in and reduction of energy barriers for sharing the facts. Finally, to measure the effectiveness of the project, we have an aggressive longitudinal data collection design that annually measures perceptions in ~60 departments. This work is supported by NSF DUE-1821710 & 1821462.

---

Symposium Talk 1

### Data mining: Helping faculty develop an accurate picture of the teaching profession in their region

**Primary Contact: Drew Isola, Get the Facts Out - AAPT**
**Co-authors: Wendy K. Adams, and Allison M. Costley, Colorado School of Mines**

A critical component of the Project's Theory of Change are the faculty who become local champions and take it upon themselves to get the facts out about the teaching profession. To be successful, these faculty must customize the project resources with local teacher salaries and retirement information. Workshops and detailed instructions on the project website have been provided; however, we have found that the expertise and time required to collect this data and to customize the resources is posing an unacceptable energy barrier. In addition, we have found that national salary data is unreliable to the point that we are uncomfortable making claims about the profession using this data. To solve both of these problems, we have embarked on a data collection effort and developed a metric for comparing tangible teacher benefits to the local economy.

---

Symposium Talk 2

### Faculty perceive they are more supportive than their perceptions may suggest...

**Primary Contact: Wendy K. Adams, Colorado School of Mines**
**Co-authors: Jared B. Breakall and Savannah L. Logan, Colorado School of Mines; Richard Pearson III, Embry-Riddle Aeronautical University; Brian Pyper, Brigham Young University - Idaho**

To measure the impact of the Get the Facts Out project over time, we have engaged in a 5-year longitudinal study of both faculty and student perceptions of the teaching profession. We are collecting large scale quantitative data via survey instruments from ~60 physics, chemistry and math departments

across the U.S. as well as visiting six of these universities so that we may collect qualitative data to better inform the survey data. In this presentation we will share the baseline data which shows a striking difference in perceptions between students who want to teach and those who do not. Additionally, this data reveals inconsistencies in faculty perceptions of teachers and their careers with faculty perceptions of students and how they advise them. Finally, insights from our site visits will be shared.

---

Symposium Talk 3

## Research-based, User-tested Materials for Recruiting STEM Teachers

**Primary Contact: Savannah L. Logan, Colorado School of Mines**
**Co-authors: Jared B. Breakall and Wendy K. Adams, Colorado School of Mines**

There is a serious shortage of secondary science and math teachers across the United States. Part of this shortage can be attributed to a lack of research-based recruitment materials. To this end, we have developed written and visual materials for recruiting future STEM teachers as part of the Get the Facts Out (GFO) project. We have tested and refined our materials through faculty and student focus groups at several demographically and geographically diverse US universities over the last two years. Recently, we collected large-scale data via a national online survey that will be shared here for the first time. Our findings provide insights into optimal recruitment strategies, and we will share our unique considerations for different locations, demographics, and target audiences. We will also discuss our testing and refinement strategies through interactive activities.

---

Symposium Talk 4

## Survey development and analysis for Getting the Facts Out

**Primary Contact: Brian Pyper, Brigham Young University - Idaho**
**Co-authors: Jared B. Breakall, Savannah L. Logan, and Wendy K. Adams, Colorado School of Mines; Richard L. Pearson III, Embry-Riddle Aeronautical University**

Following the development of the PTaP - Perceptions of Teaching as a Profession – survey, which measures students' interest in and views of teaching as a career, we developed the PTaP.HE (p-taffy) - Perceptions of Teaching as a Profession for Higher Education - which measures university faculty's perceptions of teaching as a profession. As part of the development and validation of the PTaP.HE instrument we have conducted faculty interviews, collected large-scale data from over 40 institutions, and conducted statistical analyses including a factor analysis. Here we will share the outcomes of the factor analysis, a scoring strategy, and preliminary results. We will also discuss the potential impact of faculty perceptions of the teaching profession on our future science and math teacher workforce.

## Thursday, July 23, 1:00pm EDT
## Parallel Session Cluster III: Talk Symposium

### Assessing Teaching Effectiveness: We Need More Than Just Student Evaluations

**Emily Alicea-Munoz, School of Physics, Georgia Institute of Technology**
**Co-authors: Presenters: Paul Bergeron, Michigan State University; Charles Henderson Western Michigan University; Alanna Pawlak and Noah Finkelstein, Center for STEM Learning, University of Colorado Boulder**

Effective teaching that leads to better student learning outcomes is a goal for physics instructors at all levels, as well as for training programs (e.g., workshops for new faculty or teaching assistants) and for administrators. When it comes to promotion and tenure, teaching effectiveness is usually reduced to one number, the instructor's score for "overall effectiveness" in their end-of-semester student evaluations. While it is important for instructors to receive feedback from their students, we must keep in mind that students are not experts; additionally, research has shown that student evaluations can come with a plethora of biases (gender, language, ethnicity, etc.). In this session, we explore what it means for teaching to be effective, and discuss ways in which teaching effectiveness can be evaluated that do not exclusively rely on one single score given by students at the end of the semester.

---

Symposium Talk 1

### Assessment of teaching effectiveness: Lack of alignment between instructors, institutions, and research recommendations

**Primary Contact: Charles Henderson, Western Michigan University**
**Co-authors: Chandra Turpen and Melissa Dancy**

Ideally, instructors and their institutions would have a shared set of metrics by which they determine teaching effectiveness. We asked 72 physics instructors to describe how they and their institutions assess teaching effectiveness. Results suggest that institutions typically base most or all of their assessment of teaching effectiveness on student evaluations of teaching. Instructors, on the other hand, base most or all of their assessment of teaching effectiveness on student exam performance and nonsystematic formative assessments. Few institutions and instructors use assessment practices suggested by the research literature. In general, instructors are much more positive about the methods they use to evaluate their teaching than the methods their institutions use to evaluate their teaching. Both instructors and institutions could benefit from broadening the assessment sources they use to evaluate teaching effectiveness through increased use of standardized measures based on student learning and greater reliance on systematic formative assessment.

---

Symposium Talk 2

### Holistic Teaching Evaluations and Knowledge in Use

**Primary Contact: Paul Bergeron, Michigan State University**

A growing body of work is cementing the need to move past problematic end-of-the-semester, student evaluations as the main method of evaluating teaching. Certainly, reducing the complex process of

instruction and its results to even handful of numbers should be expected to be inaccurate. To address these concerns, work at Michigan State University is ongoing to create a more holistic evaluation of teaching grounded not just in student feedback but also reflection by the instructors themselves. Of particular importance is the focus not just on the content taught but on students putting that knowledge to use. From this perspective, we believe that the Scientific Practices of the Next Generation Science Standards offer a boon to both instruction and the evaluation thereof, the implementation of which have been studied at the college level by our research team.

---

Symposium Talk 3

## The Teaching Quality Framework Initiative: Valuing and Improving Teaching and Teaching Evaluation

**Primary Contacts: Alanna Pawlak and Noah Finkelstein, Center for STEM Learning, University of Colorado Boulder**
**Co-authors: Sarah Andrews, Dena Rezaei, Joel Corbo, and Mark Gammon**

Undergraduate teaching evaluation systems often poorly measure teaching effectiveness and lack processes for formative development of teaching quality. In response to these concerns, the Teaching Quality Framework Initiative (TQF), a Center for STEM Learning project at the University of Colorado Boulder, is creating a process for transformation of teaching evaluation toward a more scholarly and evidence-based approach. The TQF, as part of the Bay View Alliance and multi-institution TEval collaboration, focuses on teaching evaluation in order to improve instruction and enhance student outcomes, among other long-term institutional objectives. Departmental-level and stakeholder meetings are combined with outreach to administrative officials and cross-departmental sharing of resources to create campus-wide change. We present tools and processes associated with departmental-level and campus-level change, explore how departments move through this process, share example tools developed by teams, and engage in conversations around mechanisms to create sustainable campus-wide change and disseminate tools/processes beyond our campus.

---

Symposium Talk 4

## Using formative assessment to improve the teaching effectiveness of teaching assistants

**Primary Contact: Alexandru Maries, University of Cincinnati**

Teaching assistants (TAs) across the United States play an important role in the education of students, as they often teach laboratories, recitations, and discussion sections. Due to increased recognition of the importance of student-centered instruction and active learning, TAs are often required to implement instructional strategies they are unfamiliar with. Thus, professional development programs designed to help TAs implement student-centered instruction effectively are very important, and one central component of any successful program is integrating formative assessment throughout. In this talk, I will describe such a program with a focus on how formative assessment is used, not so much to evaluate the TAs, but to provide feedback and support to help them grow into effective educators.

## Thursday, July 23, 1:00pm EDT
## Parallel Session Cluster III: Juried Talk Session

**Juried Talks III**

**PERC Organizing Committee**

---

Juried Talk 1

### A Formative Feedback Mechanism Shaped by Learning Assistants

**Primary Contact: Paul C. Hamerski, Michigan State University**
**Co-authors: Paul W. Irving and Daryl McPadden, Michigan State University**

Formative feedback's usefulness and power have been thoroughly demonstrated, though the way it is administered varies greatly by context. We illustrate how undergraduate Learning Assistants (LAs) interact with a formative feedback mechanism employed in a flipped, introductory physics course at Michigan State University. Feedback is given in this class via weekly, individualized, written evaluations from LAs to their students, with the goal of improving scientific practices. Our interpretivist case study on the feedback mechanism demonstrates how and why LAs carry out feedback in the ways they do. We find that the LAs take on central roles in interpreting and implementing the feedback mechanism. The LAs' unique perspectives on feedback suggest that they should have a seat at the table in deciding how a feedback mechanism like this one should be implemented.

---

Juried Talk 2

### Associations Between Learning Assistants, passing introductory physics, and equity: a QuantCrit Investigation

**Primary Contact: Ben Van Dusen, Iowa State University**
**Co-authors: Jayson Nissen**

Physics courses often have high failure rates that may disproportionately harm students who are marginalized by racism, sexism, and classism. We examined the associations between Learning Assistant (LA) supported courses and equity in non-passing grades (DFW) in introductory physics courses. The data used in the study came from 2312 students in 41 sections of introductory physics courses at a regional Hispanic serving institution. We developed hierarchical generalized linear models of student DFW rates that accounted for gender, race, first-generation status, and LA-supported instruction. We used a quantitative critical race theory (QuantCrit) perspective focused on the role of hegemonic power structures in perpetuating inequity. Our QuantCrit perspective informed our research questions, methods, and interpretations of findings. The models associated LAs with overall decreases in DFW rates and larger decreases for students of color than their white peers. While inequities in DFW rates were lower in LA-supported courses, they were still present.

---

Juried Talk 3

## Evaluating impact of GTA training in a mixed-reality classroom simulator

**Primary Contact: Tong Wan, University of Central Florida**
**Co-authors: Constance M. Doty, Ashley A. Geraets, Christopher A. Nix, Erin K. H. Saitta, and Jacquelyn J. Chini, University of Central Florida**

We evaluate the impact of rehearsing teaching skills in a classroom simulator on GTAs' instructional practices in combined tutorial and laboratory sections of an algebra-based introductory physics sequence over three semesters. GTAs participated in different numbers of simulator rehearsal sessions across the three semesters: no simulator training, one session, and four sessions. We conducted 109 classroom observations for 23 GTAs, using a modified version of Laboratory Observation Protocol for Undergraduate STEM (LOPUS). To classify and characterize GTAs' instructional practices, we conducted a hierarchical cluster analysis and found three instructional styles: "the group-work facilitators", "the whole-class facilitators", and "the waiters." These instructional styles vary in multiple GTA codes, including amount of wait time and posing questions in small groups and whole class. We discuss the characteristics of the instructional styles, distributions of GTAs' use of the styles in each semester, and the correlation between student learning outcomes and GTA instructional styles.

---

Juried Talk 4

## Investigating Similarities and Differences across Unprompted and Prompted Student-generated Diagrams

**Primary Contact: Michael Vignal, University of Colorado Boulder**
**Co-authors: Bethany R. Wilcox, University of Colorado Boulder**

Diagrams in physics communicate ideas and can aid in problem solving. Many researchers have explored student use of professional representations in physics, however characterizing spontaneously-generated diagrams from student problem solving has proven difficult. Using data from problem-solving interviews with undergraduate and graduate physics majors, we compare unprompted and prompted student-generated diagrams across six physical contexts. Informed by the distributed cognition and resources frameworks, we explore how extensively students spontaneously externalize physical details during problem solving as well as which diagramming resources students employ in different settings. We found that, overall, students correctly answered questions if they could generate accurate diagrams in a particular physical context, regardless of the extent to which they did so (without prompting) during problem solving. This finding, and our subsequent in-depth qualitative analysis across the six physical contexts, can help instructors create alignment between their learning goals, instruction, and assessment regarding diagrams in physics.

## Thursday, July 23, 1:00pm EDT
## Parallel Session Cluster III: Workshop

### Measuring and improving Pedagogical Content Knowledge of student assistants in introductory physics classes

**Jianlan Wang, Texas Tech University**
**Co-authors: Beth Thacker, Kyle Wipfli, Stephanie Hart**

Student assistants (SA), including graduate and undergraduate teaching/learning assistants, are pivotal to non-traditional physics instruction in large classrooms. Despite its effectiveness, little is known about how SAs' Pedagogical Content Knowledge (PCK) affects SA-student interactions and how those interactions promote students' learning. We are particularly interested in SA's PCK of questioning (PCK-Q) skills. In this workshop, we will present a 6-level coding scheme to analyze SA support in different vignettes of SA-student interactions in class videos. The frequency of certain levels in multiple vignettes could suggest a measure of SA's performed PCK-Q. We will also present a written instrument with open-ended questions assessing SAs' narrated PCK-Q in given situations which are drawn from vignettes of authentic SA-student interactions. We will demonstrate the process of developing and validating the coding scheme and written instrument and their use in studying SAs' impact on students' conceptual understanding of physics and critical thinking skills.

## Thursday, July 23, 1:00pm EDT
## Parallel Session Cluster III: Talk Symposium

### Promoting Successful Change in Physics Education and Research

**Rebecca Lindell, Tiliadal STEM Education: Solutions for Higher Education**
**Co-authors: Rebecca Rosenblatt, Tiliadal STEM Education: Solutions for Higher Education**

In this talk symposium/ panel discussion, we will have four invited speakers who will discuss their roles in promoting successful institutional, departmental and nationwide change within Physics Education and Research. Educational Change is not easy with many stake holders being averse to change. As the report Levers of Change: An Assessment of Progress on changing STEM instruction points out, "we are often guided, implicitly or explicitly, by a faculty deficit model that assumes that the reason instructors do not adopt new teaching practices lies primarily within the individuals, rather than problems in the higher education system or society as a whole." Within this system thinking, it is not enough to create new curriculum or to show its effectiveness, but rather too successfully promote change we need change leadership from within the physics education community at all levels. The four speakers chosen will discuss how they affected change within physics education.

---

Symposium Talk 1

### Departmental Change Through Instructional Reform: How Purdue Transitioned to Matter & Interactions

**Primary Contact: Andrew S. Hirsch, Purdue University**

At Purdue University, all physics, chemistry and engineering majors (N>2400 annually) take at least one semester of their calculus-based introductory physics sequence using the innovative texts, Modern Mechanics and Electric and Magnetic Interactions by Ruth Chabay and Bruce Sherwood. In this presentation, I will share the rationale and the unexpected steps taken in adopting these innovative texts. Having now had over a decade's experience teaching both these courses, I will share my thoughts on the challenges and successes of this change.

---

Symposium Talk 2

### Educational Change from an Administrator's Perspective

**Primary Contact: Edmund Bertschinger, Massachusetts Institute of Technology**

As the field of Physics Education Research continues to generate additional insight and understanding into the learning process, as well as advice and techniques to improve student learning outcomes, we are frequently faced with challenges of awareness of the latest scholarship and adoption of new strategies. In addition, the overall educational landscape continues to evolve very rapidly. In this presentation, I will discuss these issues from the perspective of an administrator at the departmental, college and campus level. Physics education research has successfully driven change for the better, but there are opportunities to expand the benefits further, within the field of physics and beyond.

---

Symposium Talk 3

## Promoting Institution Change: PER and Policy Working Together

**Primary Contact: Rebecca Rosenblatt, American Association for Advancement of Science**

After working as a Physics Education Researcher for nearly 15 years, I received the opportunity to serve as an American Association for the Advancement of Science - Science and Technology Policy Fellow (AAAS-STPF) at the National Science Foundation (NSF) in Division of Undergraduate Education. I pursued this fellowship to explore the role of policy in STEM Education. In this talk, I will present lessons I have learned through this fellowship including ways that policy effects education and education research, and the roles policies play in leading change in education. Additionally, I will reflect on what I have learned about how funding agencies like NSF enact change through policy and reflect on ways that the Physics Education Research community could use this to be more impactful change leaders for science education.

---

Symposium Talk 4

## Systemic Change: TEAM-UP and Beyond

**Primary Contact: Edmund Bertschinger, Massachusetts Institute of Technology**

The AIP TEAM-UP report identifies the structural and systemic causes explaining why African Americans have not experienced the growth in bachelor's degrees in physics the way they have in other fields or as other minority groups have experienced in physics over the past two decades. Solving these problems requires changing not only the way physicists train students, but how they think about training students. Research on change in higher education suggests the need for physicists and astronomers to recognize and question the norms, values, and culture of their fields. The TEAM-UP report, SEA Change, and the new APS-IDEA all seek to stimulate and sustain a cultural transformation in the profession.

## Snack & Chat

## Wednesday, July 22, 4:30PM EDT

**This Way to the Future: A Discussion of Themes and Predictions in Science Fiction**

*Raymond Zich & Rebecca Rosenblatt*

If you enjoy science fiction in any medium (books, TV, lithograph), and are interested in discussing ideas presented or predictions that have been, have not been, or might be correct with others, perhaps in the context of policy, feel free to join us for this Snack and Chat!

Prompts to ponder:

- What do you think of using technology to trace COVID?
- Can you think of science fiction in which the future is not dystopian and/or is not recovering from dystopia?
- How far are we from body modifications, as seen in William Gibson's Neuromancer, and should we be implementing proactive policies?
- Are technology control or population limitations as depicted in Larry Niven's Known Space series advantageous or detrimental? Are these things likely or unlikely to happen?
- Does the Expanse provide realistic scenarios of international space diplomacy?
- If you had to write a science fiction story, what would it be on?

**Why diversity-driven efforts make sense for physics education**

*Eric Kuo*

I've found that many of my physics colleagues support the importance of diversity in physics education but still have honest questions about the logic and fairness of diversity-driven efforts around recruitment, pedagogy and department culture. This discussion will side firmly with these diversity-related efforts, while inviting people to think about the honest questions that people might have about them. Our aim is not to "win the argument," but to exchange ideas about diversity-driven actions in physics, without fear of judgment, to better understand the "diverse" perspectives of people who support diversity and how to respond to these honest questions. Please bring an "honest question" about diversity-related efforts that you've had or heard, a desire for mutual understanding, and an open heart/mind.

**Labs**

*Natasha Holmes*

PER has a growing community focusing on studying student experiences in labs. This Snack and Chat aims to bring that group together to connect, share research ideas, and just chat all things labs!

**Catching up with our pets**

*Jennifer Blue*

Many of us have been working from home for months, and our pets have gotten to know us even better than they wanted to. But do our pets know our colleagues? Some of them already do, I'm sure! Let's have a very informal snack and chat, with the only agenda to shine our webcams on the non-humans we share our homes with.

**Learning Analytics**
*Carolyn Sealfon*
Let's chat about how beautiful mathematics, statistics and algorithms can be applied in human-centered ways to improve learning experiences for diverse learners. How can we can build connections between the great work in the Learning Analytics and Educational Data Mining communities and the great work in the PER community?

**Tackling the Challenges of Online Active Learning: Strategies, Resources and Opportunities**
*Zhongzhou Chen*
Almost all of us are faced with the challenge of teaching our students entirely online this coming Fall, and we can all do a better job if we find effective ways to collaborate and share. What are effective strategies for actively engaging students online, while being as flexible as possible to accommodate the various challenges students are facing? How can we better organize, create and share resources? What opportunities will online learning provide for instructional innovation and educational research?

**Working with Learning Assistants in Introductory Physics Courses**
*Sujata Krishna*
We will share our experiences with LA training, prep and practice work. Discussions will focus on the feedback received from LAs to help improve their experience, to use of specific technological tools, and on moving the LA course online. It will be a wide ranging open discussion and you are encouraged to bring your food to the meeting - or at least a cup of coffee!

**Teaching all students from any school about all of the Sciences**
*Don Franklin*
Science of Energy- How every high school student should have a knowledge of all the sciences. Even the most rural or poorest schools can prepare their students for Trade or Academic Schools. The ebook is free to download!

**Positive Psychology in teaching physics**
*Rahmat Rahmat*
Implementing Positive Psychology can help physics students understand the beauty of physics. We will discuss how Positive Psychology can be helpful in developing positive attitudes toward learning physics.

**Super Celebration of a Loved, Exceptional, and Unique Person: Honoring Bob Beichner**
*Brandon Lunk*
Primarily known as the creator of SCALE-UP and the founding editor of Phys. Rev. PER, Bob Beichner has been a highly influential member of the PER community for many years. In addition to a robust and lengthy research career (including the development of research validated assessment instruments like the TUG-K), he was also instrumental in building ways for us to come together as a community (e.g., early PERC, PER-CENTRAL, etc.). Now that Bob is officially retiring, we want to celebrate him at his last national meeting. This snack & chat will mostly involve open time for people to socialize and to share their own stories about the impact that Bob has had on them personally and on our community. All are welcome! Please, also, feel free to pop in and out as you wish.

**Answer fairies or facilitators? What are we bringing into introductory physics courses with teaching/learning assistants?**
*Jianlan Wang, Beth Thacker, Kyle Wipfli, & Stephanie Hart*
Student assistants (SA), including graduate and undergraduate teaching/learning assistants, are pivotal to non-traditional physics instruction in large classrooms. Despite its effectiveness, little is known about how SAs affect student learning. What competences should SAs be prepared with to effectively attend students' learning? What should be the role of SAs in their interaction with students, authority, more knowledgeable others, or peers who inquire together with students? What pedagogical knowledge or skills do SAs need to possess, providing academic feedback, questioning, or scaffolding group interaction? How should SAs be prepared with those pedagogical competences, receiving instruction about educational theories, participating in educational research, gaining practical knowledge from empirical experiences through trial and error, imitating experts' practices of physics

teaching, or reflecting on videos of SAs' teaching practice through meta-cognition? What is the most efficient approach considering the limited time for SA preparation? Welcome to join us to discuss those questions.

**Matter & Interactions**
*Bruce Sherwood*
A get-together for current and prospective users of the Matter & Interactions textbook.

**Challenges in amusement parks: First-person physics**
*Ann-Marie Pendrill*
Many schools visit amusement parks and students bring back experiences, photos, videos and data.
Forces experienced by our body may be captured by a smartphone and analysed in the classroom
Textbook examples come to life, but may appear different when the body in Newton's laws is our own.

How can we best make use of related learning opportunities when motions are no longer restricted to one dimension or constant velocity or acceleration, and includes rotation? What is the best way to prepare and follow up a visit for students with different backgrounds? What are the most productive teacher roles during the visit?

With a background in computational atomic physics, I have used amusement park examples in my teaching, for physics, teaching and engineering students and also arranged large scale science and technology days in Sweden's largest amusement parks. Some of the work can be found in papers listed at http://tivoli.fysik.org/english/articles/

**Sharing your science (aka science communication)**
*Nick Young*
We have spent the past few days sharing our research with our colleagues. But how do you share your work beyond the research community? In this snack and chat, we will discuss ways we communicate research outside of academia and brainstorm new methods. Maybe you are interested in sharing research through outreach events or including current research in your classes. We can talk about those too! By attending this snack and chat, you will come away with new ideas about communicating science, regardless of where you plan to apply them.

**Lab courses during a pandemic**
*Ben Pollard, et al.*
This is a breakout topic under Natasha Holme's chat about labs. If there's enough interest and a need for two groups, we'll use this space to chat about physics labs and remote instruction. We can share a variety of creative approaches employed by instructors in order to create remote lab classes, and offer some insight into the impact on students' beliefs about experimental physics.

## Acknowledgements

The PERC 20/20 organizers would like to give a sincere thank you to all who we have interacted with over the past several months regarding this year's conference. Such interactions include but are not limited to conversations, Twitter exchanges, email conversations, and blog entries/replies. While the change in venue from a physical conference to a virtual one has presented challenges, we are grateful for the support exhibited from our colleagues, our peers, our supporters: our PER community. Whenever a list such as this is published, there is always the risk of leaving off individuals who should have been included. Please know that we appreciate all of those whose dialogue helped move us forward.

| **PERC 20/20 Panelists** | | |
|---|---|---|
| Geraldine Cochran | Sarah McKagan | Susan Singer |
| Joseph Krajcik | Valerie Otero | Robert Tai |

| **Organizational** | | |
|---|---|---|
| PERLOC, every member! | Jerri Anderson (AAPT Staff) | Sol Rosenberg (Underline) |
| Lyle Barbato (all PERC organizers: get to know Lyle!) | Chandralekha Singh | Jernej Masnec (Underline) |
| | Jan Mader (AAPT SM20 Co-Chair) | Luka Simic (Underline) |
| Tiffany Hayes (AAPT Staff) | Toni Sauncy (AAPT SM20 Co-Chair) | Darrell Gunter (Underline) |
| Cerena Cantrell (AAPT Staff) | | |

| **Session and Snack & Chat Organizers** | | | |
|---|---|---|---|
| Ann-Marie Pendrill | Claudia Fracchiolla Dawn | Jianlan Wang | Raymond Zich |
| Ben Pollard | Meredith | John Thompson | Rebecca Lindell |
| Beth Thacker | Dimitri R. Dounas-Frazer | Kyle Wipfli | Rebecca Rosenblatt |
| Brandon Lunk | Don Franklin | Natasha Holmes | Smadar Levy |
| Brian Pyper | Edit Yerushalmi | Nick Young | Stephanie Hart |
| Bruce Sherwood | Emily Alicea-Munoz | Rachel Henderson | Sujata Krishna |
| Carolyn Sealfon | Eric Kuo | Rahmat Rahmat | Zhongzhou Chen |
| Chris Orban | Jennifer Blue | Ramon Barthelemy | ***And all PERC presenters!*** |

| **Twitter Interactions** | **PERC 20/20 Blog Interactions** |
|---|---|
| Abby Kimbrough (they/them) @thephysicsman | Angie Little |
| Brian Frank @brianwfrank | Bob Beichner |
| Brian Lane @WBrianLane | Chandra Turpen |
| David Marasco @ThePhysicsShow | Dimitri Dounas-Fraser |
| Debbie Andres @MsA_Physics | Helen Mae Cothrel |
| Johan Tabora @JohanTabora | Joel Corbo |
| Marta R. Stoeckel @MartaStoeckel | JT Laverty |
| Moses Rifkin @RiPhysKin | Laura McCullough |
| Nicole Murawski @physicsnico | Mel Sabella |
| Sarah Johnson @SJDJ | Michael Wittmann |
| Susan Meahb Kelly @S_M_Kelly | Nicholas Young |
| (& many more!) | Todd Zimmerman |

| **Other Communication/Interactions (including panelist question submissions)** | | | |
|---|---|---|---|
| Ayush Gupta | Brian Zamrippa Roman | Deborah Lynn | Michael Loverude |
| Bob Hilborn | Bruce Mason | Erin E. Flater | Mohammad AlFiky |
| Brad Ambrose | Bruce Sherwood | Jane Jackson | Rachel Henderson |
| Brandon Lunk | Craig Wiegert | Laszlo Frazer | Ramon Barthelemy |
| Brian Frank | Danny Doucette | Katherine Prammer | Tor Ole Odden |