



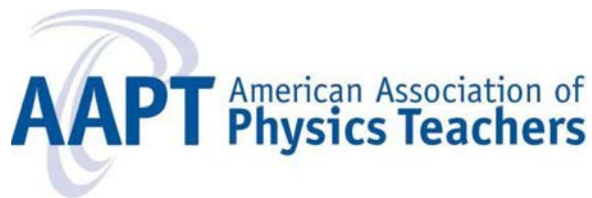
# 2024 PHYSICS EDUCATION RESEARCH CONFERENCE

Boston, Massachusetts

July 10-11, 2024

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## Preface

The theme of the 2024 Physics Education Research Conference (PERC) was “*Bridging the Institutional Gap: PER at Primarily Undergraduate Four Year Institution, Two-Year College, and K-12 Levels*”. This theme invited attendees to explore the difficulties that can arise when teachers at non-doctoral-granting institutions or K-12 schools attempt to adopt the recommendations of physics education research conducted at doctoral universities. The organizing team, Andrew J. Mason, Carina Rebello and Tianlong Zu, explicitly set out to address these difficulties constructively. The organizers designed a conference that featured ways to bridge this gap. The committee was supported in their efforts by leadership from both the American Association of Physics Teachers (AAPT) and the PER Leadership and Organization Council (PERLOC).

The plenary sessions featured examples of efforts to implement or adapt PER at non-doctoral institutions and K-12 schools, including collaborations between doctoral and non-doctoral institutions or K-12 schools. The plenary speakers were (in order of presentation): Thomas J. Noviello; Abigail Daane, Anthony Escudro and Sherry Savrda; Catherine H. Crouch and Benjamin D. Geller; and Jennifer Docktor.

The conference theme was also explored in several Community Connections sessions, Parallel Sessions, and contributed poster presentations. In addition to the sessions and presentations focused on the conference theme, the remainder of the sessions and presentations represent the breadth of current research within PER. The papers published in this Proceedings therefore represent an annual snapshot of the field.

The 2024 PERC Proceedings process would not be possible without the ongoing support of Lyle Barbato, who works closely with the editors each year. The sponsorship of AAPT and open-access publishing through ComPADRE have allowed the PERC Proceedings to continue to evolve and improve.

Francette Fey provided much-needed administrative support to the editors. Her assistance was critical to ensuring that the peer review process went smoothly and stayed on schedule.

The peer review process for the PERC Proceedings cannot function without the efforts of those community members who volunteer their time and expertise each year. The editors gratefully acknowledge all of those who participated in the review process:

Mohamed Abdelhafez, Adrian Adams, Emily Alicea-Munoz, Winter Allen, Jared Arnell, Roshni Bano, Lauren Barth-Cohen, Ramon Barthelemy, Lauren Bauman, Scott Bonham, Andrew Boudreaux, Brett Boyle, Amir Bralin, Bill Bridges, Mary Brundage, Eric Burkholder, Ryen



Burris, Garrick Burron, Alexis Buzzell, Ying Cao, Larissa Carter, Cai Cash, Ravishankar Chatta Subramaniam, Zhongzhou Chen, Jacquelyn Chini, Geraldine Cochran, Lauren Collins, John Colton, Luke Conlin, Alexander Conte, Joel Corbo, David Craig, Abigail Daane, Robert Dalka, Claudia De Grandi, Ian Descamps, Jacqueline Dippre, Vincent Doan, Jonan Donaldson, Constance Doty, Thanura Ediri, Boyd Edwards, Shams El-Adawy, Andrew Elby, Tatiana Erukhimova, Noah Finkelstein, Scott Franklin, Emily Frederick, Karl Henrik Fredly, Rebeckah Fussell, Gregory Gallagher, Andy Gavrin, Jordan Gerton, Apekshya Ghimire, Bor Gregorcic, Molly Griston, Alia Hamdan, Razan Hamed, Patti Hamerski, David Hammer, George Hassel, Zahra Hazari, Kenneth Heller, Rachel Henderson, Chloe Hennessy, Pachi Her, Paula Heron, Jessica Hoehn, Natasha Holmes, Maria Horak, Mike Hull, Tra Huynh, Borge Irgens, Safana Ismael, Sophia Jeon, Shulamit Kapon, Jaya Shivangani Kashyap, Ebba Koerfer, Kentaro Kojima, Hannah Kramer, Micah Kretchmer, Jesse Kruse, Mila Kryjevskaja, Eric Kuo, Jay Kurima, Aakash Lakshmanan, James Laverty, Vy Le, Anne Leak, Noah Leibnitz, Heather Lewandowski, Yangqiuting Li, Jerome Licini, Qiaoyi Liu, Morten Lundsgaard, Aidan MacDonagh, Maggie Mahmood, Danielle Maldonado, Nathalia Martinez Garcia, Clausell Mathis, Michele McColgan, Sarah McHale, David Meltzer, Rachael Merrit, Jennifer Mesiner, Jason Morphew, David Neilsen, Jayson Nissen, Tor Ole Odden, Daniel Oleynik, Christopher Overton, Daniel Pacheco, Kamyar Pashayi, Maya Patel, Kayleigh Patterson, Ida Friestad Pedersen, Jonathan Perry, Anna Phillips, Keshab Pokharel, Giulia Polverini, Geoff Potvin, Parker Poulos, Brean Prefontaine, Gina Quan, Jennifer Radoff, N. Sanjay Rebello, Tom Reshef Israeli, Amy Robertson, Idaykis Rodriguez, Rebecca Rosenblatt, Minjung Ryu, Erin Saitta, Lisabeth Santana, Lilit Sargsyan, Toni Sauncy, Sean Savage, Erin Scanlon, Carolyn Sealfon, David Seiden, Devyn Shafer, Daniel Sharkey, Katey Shirey, Amogh Sirnoorkar, Mathilda Smith, Trevor Smith, Al Snow, Christian Solorio, John Speirs, Sarah Stella, Tim Stelzer, John Stewart, Meagan Sundstrom, David Syphers, Hamideh Talafian, Beth Thacker, Chandra Turpen, Ben Van Dusen, Gautam Vemuri, Michael Verostek, Tong Wan, Nandana Weliweriya Liyanage, Suzanne White Brahmia, Bethany Wilcox, Julia Willison, Jun-ichiro Yasuda, Nicholas Young, Yiyuan Zhang, Charlotte Zimmerman, and Benjamin Zwickl.

Sincerely,  
Qing X. Ryan  
Andrew Pawl  
Justyna P. Zwolak

# **PERC 2024: Bridging the Institutional Gap: PER at Primarily Undergraduate Four Year Institution, Two-Year College, and K-12 Levels**

## **Conference Overview**

The theme of PERC 2024 was “*Bridging the Institutional Gap: PER at Primarily Undergraduate Four Year Institution, Two-Year College, and K-12 Levels.*” There are several reasons and inspirations for this focus. The primary, deeper concern that inspired this theme regards a reflection upon the original definition of PER as a field, its progression over the past several decades, and concerns for ensuring its health and growth as a field into the future. The PERC 2024 organizing team, and PERLOC’s PERC liaisons, believe that a necessary dimension of this health and growth is for PER principal investigators to plan and pursue their own research projects at different teaching-focused institution types, in addition to continued growth of PER at the research university level, as one might expect of research in any other recognized physics field at teaching-focused institutions.

Second, as indicated by the theme, among the gaps in PER literature (see Kanim and Cid, “Demographics of physics education research,” *Phys. Rev. PER* 16, 020106, © 2020) is a gap in research by institution type, specifically that large research institutions dominate the literature as host institutions for PER, even though they constitute a relatively small percentage of all institutions of higher learning. For this reason, as well as the reason stated above, it is both necessary and natural for the field to grow outward into different institution types, to more properly serve physics students at all institution types, as well as upward towards new research topics and forward into new research-based techniques. Similarly, beyond higher education, there is a dearth of literature on K-12 physics and physical science students. The K-12 physics student population is critically important to understand and address for several reasons: formation of physics content knowledge prior to higher education, both domestically and abroad; the broad general education goals of the K-12 system in the United States; and the understanding of deep background variables that may influence higher education student outcomes (e.g. misconceptions and socioeconomic background impact) from beyond the reach of higher education institutions.

Third, teaching-focused institutions have different student populations, classroom formats, etc. than do the research universities from which the research-based instruments and project leads, and these populations need to similarly be studied and understood on their own terms, as opposed to simply implementing research-based instruments and techniques or gathering data as a non-lead institution. We believe that a major source of frustration for PER researchers and practitioners across all institution types (including research institutions) is the persistent difficulty of research-based techniques being implemented successfully across different institutions. As an aside to this concern, the strong need for replication studies is especially pronounced at teaching-focused institutions, because their student populations are less well understood than are research university student populations.

Finally, and importantly, the organizing team and PERLOC liaisons recognized an overlap of the PERC 2024 theme with the PERC 2023 theme, “*Working Together to Strengthen PER Community*”

*of Practice.*” The idea of a community of practice within PER influenced decisions on the conference organization both in abstract ways, e.g. including the recognition of research university PER groups in assisting teaching-focused university PER towards the goals of the theme (both the need for this cooperation, and crediting successful examples therein); and in more concrete ways, e.g. retaining the more informal “community connections” sessions alongside the more formal parallel sessions within the schedule.

The PERC 2024 organizing team therefore believes that a necessary plan for future PER and development is to assist researchers at teaching-focused institutions in running their own projects – as original research projects from PIs at these institutions, and/or in collaboration as co-PIs with research universities. Demonstrating the validity of, and need for, PER as a physics research field at these institutions is a logical next step forward for the growth of the field overall.

### **Organizers**

Andrew J. Mason, University of Central Arkansas  
Carina Rebello, Toronto Metropolitan University  
Tianlong Zu, Northwestern University

### **Acknowledgments**

The PERC 2024 organizers deeply appreciate everyone who worked to make this conference successful, as follows. Among the following acknowledgements, the organizers would particularly like to thank the invaluable assistance of Rebecca Lindell and Raymond Zich in their roles as PERLOC liaisons, as well as their contributions as session organizers, and the equally invaluable assistance of Lyle Barbato with advice, constructing the conference program, managing and updating the conference site’s content, and on-the-ground details at the conference venue.

### ***Plenary Speakers:***

Catherine H. Crouch, Swarthmore College  
Abigail R. Daane, South Seattle College and OPTYCs  
Jennifer Docktor, University of Wisconsin – La Crosse  
Anthony Escuadro, Harold Washington College and OPTYCs  
Benjamin Geller, Swarthmore College  
Thomas “TJ” Noviello, Worcester Polytechnic Institute  
Sherry Savrda, OPTYCs

We also wish to thank Kristine Lui of OPTYCs for coordinating with the OPTYCs-related plenary speakers.

### ***Parallel Session Organizers and Moderators:***

Mojca Cepic, Eleanor Close, Luke Conlin, Constance Doty, Scott Franklin, Brianne Gutmann, Alia Hamdan, Andrew Heckler, Charles Henderson, Natasha Holmes, Shulamit Kapon, Alexis Knaub, Stefan Kuechemann, Jochen Kuhn, Rebecca Lindell, Liam McDermott, Tony Moore,

Beth Parks, Eleanor Sayre, Erin Scanlon, Amoogh Sirnoorkar, David Syphers, Bud Talbot, Gary White, and Raymond Zich

***Community Connection Session Hosts:***

Toluwalase Akanbi-Akinlolu, Bill Bridges, Juan Burciaga, Rebecca Lindell, Kristine Lui, Andrew J. Mason, Sam McKagan, Beth Thacker, Raymond Zich, and Charlotte Zimmerman

***AAPT staff:***

Lyle Barbato, Tiffany Hayes, and Jamar Jennings

***PERLOC Liaisons:***

Rebecca Lindell and Raymond Zich

***PERC Proceedings Editors and Staff:***

Qing X. Ryan, Andrew Pawl, and Justyna P. Zwolak

***Financial Support:***

PERLOC and the AAPT

Finally, the PERC 2024 organizers would like to thank the attendees who came to the conference, engaged openly and respectfully, and contributed to the conference's overall success.

## PERC 2024 Schedule at a Glance

EDT	Wednesday, July 10, 2024
2:15pm	<p><b>Bridging plenaries and PERC Kickoff</b></p> <p><a href="#"><u>Fostering PER at WPI: A Path of Collaborative Engagement, Challenges, and Growth</u></a>  <i>Speaker: <a href="#"><u>Thomas J. Noviello</u></a></i></p> <p><a href="#"><u>Initiating PER Collaborations with Two-Year Colleges</u></a>  <i>Speakers: <a href="#"><u>Abigail Daane</u></a>, <a href="#"><u>Anthony Escudro</u></a>, and <a href="#"><u>Sherry Savrda</u></a></i></p>
4:00pm	<b>Poster Session 1 Setup</b>
4:10pm	<b>Poster Session 1</b> – <a href="#"><u>Abstracts and layout</u></a>
5:00pm	<p><b>Community Connections 1</b></p> <p><a href="#"><u>Conversations in the PER of the IPLS Course</u></a> - <i>Host: <a href="#"><u>J. Burciaga</u></a></i></p> <p><a href="#"><u>Initiating PER Collaborations with Two-Year Colleges</u></a> - <i>Host: <a href="#"><u>K. Lui</u></a></i></p> <p><a href="#"><u>A Gathering of Students hosted by PERCoGS</u></a> - <i>Host: <a href="#"><u>B. Bridges</u></a></i></p> <p><a href="#"><u>Building a community of Tutorial implementers</u></a> - <i>Host: <a href="#"><u>S. McKagan</u></a></i></p> <p><a href="#"><u>Whither PER? Past, Present, and Concerns about the Future</u></a> - <i>Host: <a href="#"><u>A. J. Mason</u></a></i></p>
6:00pm	<b>Dinner on your own</b>
7:25pm	<b>Poster Session 2 Setup</b>
8:00pm	<p><b>Poster Session 2</b> – <a href="#"><u>Abstracts and layout</u></a></p> <p>Presenters with odd-numbered posters presented during the first 40 minutes. Following a 10-minute transition period, presenters with even-numbered posters presented during the last 40 minutes.</p>

EDT	Thursday, July 11, 2024
8:15am	<p><b>Parallel Sessions Cluster 1</b></p> <p><a href="#"><u>Methodological Activism in Physics Education Research: Conducting Research with Minoritized Populations</u></a> (Round Table Discussion)  <i>Moderator: <a href="#"><u>A. V. Knaub</u></a></i>  <i>Presenter: <a href="#"><u>M. Ong</u></a>, TERC</i>            Preparatory Material: <a href="#"><u>The Double Bind in Physics Education by Maria Ong</u></a></p> <p><a href="#"><u>Addressing the impact of external stresses on research through empathy and care</u></a> (Critical Conversation)  <i>Moderators: <a href="#"><u>E. Close</u></a>, <a href="#"><u>S. Franklin</u></a>, <a href="#"><u>A. Hamdan</u></a>, and <a href="#"><u>B. Gutmann</u></a></i></p> <p><a href="#"><u>Solo PER: Facilitating Connectivity and Cooperation</u></a> (Round Table Discussion)  <i>Moderator: <a href="#"><u>R. Zich</u></a></i></p> <p><a href="#"><u>Journal Editors' Roundtable Discussion with Q&amp;A</u></a> (Round Table Discussion)  <i>Moderator: <a href="#"><u>N. Holmes</u></a></i>  <i>Presenters: <a href="#"><u>M. Cepic</u></a>, <a href="#"><u>C. Henderson</u></a>, <a href="#"><u>B. Parks</u></a>, and <a href="#"><u>G. White</u></a></i></p>

	<p><b><u>Learners' engagement in sensemaking (Talk Symposium)</u></b>  Moderator: <i>S. Kapon</i>  Presenters: <i>D. Hammer, S. Kapon, E. Kuo, D. Perl-Nussbaum, T. Reshef-Israeli, O. Sivan, and E. Yerushalmi</i></p> <p><b><u>Applications, Opportunities and Challenges of Large Language Models in Physics Education (Talk Symposium)</u></b>  Moderator: <i>S. Kuechemann</i>; Presenters: <i>G. Kortemeyer, S. Kuechemann, J. Kuhn, E. Latif, and X. Zhai</i></p>
9:45am	<p><b>Plenary 2</b></p> <p><b><u>Does it stick? A longitudinal study of introductory physics for life sciences at a small college</u></b>  Speakers: <i>Catherine H. Crouch</i> and <i>Benjamin D. Geller</i></p>
11:00am	<p><b>Community Connections 2</b></p> <p><b><u>Mid-career Physics Education Researchers Back on the job market</u></b> - Host: <i>R. Lindell</i></p> <p><b><u>Exploring intersectionality as a Physics education research methodology</u></b> - Host: <i>T. Akanbi-Akinlolu</i></p> <p><b><u>OISE Research, Resources and Community</u></b> - Host: <i>B. Thacker</i></p> <p><b><u>Mathematical Reasoning in Algebra-Based Physics</u></b> - Host: <i>C. Zimmerman</i></p>
12:00pm	Lunch on your own
2:00pm	<p><b>Plenary 3</b></p> <p><b><u>Physics Education Research at Primarily Undergraduate Institutions</u></b>  Speaker: <i>Jennifer Docktor</i></p>
2:30pm	<p><b>Parallel Sessions Cluster 2</b></p> <p><b><u>Ableism the unconscious bias affecting your Education Research (Critical Conversation)</u></b>  Moderators: <i>C. Doty, R. Lindell, L. McDermott, T. Moore, and E. Scanlon</i></p> <p><b><u>Can your classroom be your laboratory? The thinning veil between scholarly teaching and research (Custom Format)</u></b>  Presenters: <i>L. Conlin, D. Hammer, and P. Hutchison</i></p> <p><b><u>Seeking Significance: Conducting and Disseminating Research at Primarily Undergraduate Institutions (Round Table Discussion)</u></b>  Moderator: <i>D. Syphers</i></p> <p><b><u>Round Table on NSF Matters (Round Table Discussion)</u></b>  Moderator: <i>B. Talbot</i>  Presenter: <i>E. Sayre</i></p> <p><b><u>Redesigning Legacy Conceptual Inventories: Using Evidence Centered Design to Develop Valid, Equitable, and Flexible Items in Kinematics and Dynamics (Talk Symposium)</u></b>  Moderator: <i>A. Heckler</i>  Presenters: <i>R. Henderson, J. Stewart, and E. Christman</i></p> <p><b><u>Leveraging Artificial Intelligence in Teaching and Learning of Physics (Talk Symposium)</u></b>  Presenters: <i>A. Bralin, M. Grover, S. Rebello, and A. Sirnoorkar</i></p>
5:00pm	<b>End of PERC</b>

## **Introduction**

The 2024 Physics Education Research Conference Proceedings consists of 72 peer-reviewed papers and three plenary papers.

The peer-reviewed papers are written products of any conference presentation made during the parallel and poster sessions. Each paper undergoes a rigorous peer review process in order to be published in the Proceedings. This year there were 92 submitted manuscripts, of which 72 were accepted for final publication.

The readership of the Physics Education Research Conference Proceedings includes faculty, post-doctoral associates, and graduate and undergraduate students in physics education; scholars in other discipline-based science education or closely related fields, such as cognitive science; practitioners in physics or other sciences, such as teaching faculty at undergraduate and graduate levels, and high school physics teachers.