

2017 PHYSICS EDUCATION RESEARCH CONFERENCE

Cincinnati, OH, USA July 26 – 27, 2017

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2017 Physics Education Research Conference

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PREFACE

The theme of the 2017 Physics Education Research (PER) Conference was Mathematization and Physics Education Research. This theme was selected because of the increasing number of recent publications on mathematics in physics and also because of the growing connections between the PER community and the Research in Undergraduate Mathematics Education (RUME) community. Events and activities of this year's PER Conference revolved around discussions of how students conceptualize and proceduralize mathematical operations in the context of physics problem solving. This conference attracted nearly 400 participants and inspired them to engage in deep reflection of the current status of learners' approaches to mathematization as well as effective ways to improve their conceptual framing of mathematical procedures in physics problem solving. The participants also discussed a variety of other topics related to teaching and learning of physics.

The first Plenary Session, also serving as the AAPT-PERC bridging session, shone a spotlight on two invited speakers Michael Oehrtmann and Megan Wawro, who brought the audience from the physics kingdom into the mathematics arena. Michael Oehrtmann presented a talk titled "Quantitative reasoning and mathematical modeling in an introductory calculus sequence," in which he reported multiple studies of student development of mathematical expressions and equations. Megan Wawro presented a talk titled "Student understanding and symbolization of eigen-theory." In this talk she provided a unique lens on how students in quantum physics courses reason about and symbolize eigenvectors and eigenvalues for a 2×2 matrix.

Another highlight of the conference is the lunch program on the second day, in which three researchers—Andrew Boudreaux, Ayush Gupta, and David Meltzer shared their journeys of studying and improving student mathematical skills in physics classes.

This year's conference boasted a large number of presentations, including one (1) first-timer and undergraduate poster session, two (2) contributed poster sessions, and three (3) parallel clusters. One unique feature of this year's conference was that a new presentation format, namely juried talks, was introduced into the parallel clusters. Prior to the conference, authors of the juried talks submitted their proposals to the conference organizers for review. Accepted proposals then were developed into talks for presentation at the conference. Along with symposiums and invited presentations, juried talks allowed the authors to present their emerging findings from more mature research and to receive feedback for their future improvement. As a result of this new presentation format, this year's PERC Proceedings now includes a separate section for the five juried talks presented at the conference.

It is important to recognize and thank the conference organizers who sacrificed hours of after-work time to make the 2017 PERC successful. These individuals are: Steve Kanim, Suzanne White Brahmia, Michael Loverude, and John Thompson. Also playing crucial roles behind the scene to make the conference possible are the American Association of Physics Teachers (AAPT), and the Physics Education Research Leadership and Organizing Council (PERLOC).

As with the previous years, the 2017 PERC Proceedings online submission and review process was supported by Lyle Barbato and Bruce Mason who work closely with the PERC Proceedings

Editors to ensure smooth functioning of the online system. We owe Lyle and Bruce a great deal of thanks. The Editors also thank the AAPT for their sponsorship of the Proceedings as it is published on-line through comPADRE.

Last but not least, the Editors wish to thank the referees for volunteering their time and expertise to help maintain the quality of the papers published in the Proceedings. This year we had 222 reviewers who reviewed the 155 papers submitted to the Peer Reviewed Section.

The Editors thank: A. Bogdan, A. F. Heckler, Abhilash Nair, Abigail R. Daane, Alexander P. Becker, Alexandra Lau, Alexandru Maries, Alexis V. Knaub, Alice Olmstead, Amber Sammons, Amy D. Robertson, Andrea G. Van Duzor, Andrew Elby, Andrew Gavrin, Andrew Mason, Andrew Pawl, Andy Rundquist, Angela Little, Anna McLean Phillips, Anne E. Leak, Ayush Gupta, Bei Cai, Ben Archibeque, Ben Van Dusen, Benjamin P. Schermerhorn, Benjamin Pollard, Benjamin Zwickl, Bert Xue, Bethany R. Wilcox, Binod Nainabasti, Bor Gregorcic, Brandon R. Lunk, Brant Hinrichs, Brian D. Thoms, Brian Zamarripa Roman, Brianna Santangelo, Brianne Gutmann, Bruce Mason, C. D. Porter, Carina M. Rebello, Carolina Alvarado, Cassandra Paul, Chandra Turpen, Chandralekha Singh, Charles Bertram, Charles Henderson, Christine Lindström, Christof Keebaugh, Chrystin Green, Claudia Fracchiolla, Clausell Mathis, Corinne A. Manogue, Daniel Caravez, Danielle Harlow, David Donnelly, David Lieberman, David P. Maloney, David Roundy, Deepika Menon, Dimitri R. Dounas-Frazer, DJ Wagner, Edgar de Guzman Corpuz, Eleanor Sayre, Eleanor W. Close, Elias Euler, Elijah Tabachnick, Elise Agra, Elizabeth Gire, Emily Alicea-Munoz, Emily Marshman, Emily Moore, Emily van Zee, Eric A. Williams, Eric Brewe, Eric Kuo, Erin Ronayne Sohr, Esmeralda Campos, Felicia Davenport, Gary A. Morris, Gary Gladding, Gary White, Genaro Zavala, Geoff Potvin, Geraldine L. Cochran, Gina Passante, Guangtian Zhu, H. J. Lewandowski, Homeyra Sadaghiani, Hunter G. Close, Ian W. Founds, Inkeri Kontro, Jacob T. Stanley, Jacquelyn J. Chini, Jan-Philipp Burde, Jarrad W. T. Pond, Javier A. Pulgar, Jayson Nissen, Jean-Michel Mailloux-Huberdeau, Jeffrey W. Murray, Jennifer Blue, Jennifer Keil, Jessica Conn, Jessica L. Alzen, Jillian Schreffler, Jing Zhang, Joel C. Corbo, John R. Thompson, Jon Gaffney, Jonathan Engelman, Joseph Smith, Joshua Von Korff, Jue Wang, Justyna P. Zwolak, K K Mashood, K.N. Quinn, Katarzyna E. Pomian, Katherine Ansell, Katherine Perkins, Katherine Rainey, Kathleen Hinko, Kathleen Koenig, Kathleen T. Foote, Kathy A. Harper, Kelby T. Hahn, Kelly Boden, Kelly Martin, Kevin Lee Watson, Krista E. Wood, Kristine E. Callan, L.J. Clark, Laura A. Wood, Laura Millay, Lauren A. Barth-Cohen, Lei Bao, Lin Ding, Lindsay Owens, Lisa M. Goodhew, Lyle Barbato, MacKenzie Lenz, Manher Jariwala, Marcos D. Caballero, Marianna Lamnina, Mary Bridget Kustus, Mats Selen, Matthew Wilcox, Mel S. Sabella, Melanie Good, Melissa H. Dancy, Michael A. Greene, Michael B. Bennett, Michael C. Wittmann, Michael J. Obsniuk, Michael M. Hull, Michael Vignal, Miguel Rodriguez, Monica Cook, Monica Quezada-Espinoza, Morten Lundsgaard, N. Sanjay Rebello, N.G. Holmes, Nafis I. Karim, Nandana Weliveriya, Nathaniel T. Hawkins, Nicholas T Young, Noah Finkelstein, Pablo Barniol, Pascal Klein, Patrick Carroll, Patrick Kelley, Paul Hutchison, Paul Irving, Paul J. Emigh, Paul J. Walter, Paul Justice, Paula R. L. Heron, Peter S. Shaffer, Qing X. Ryan, Rachel E. Scherr, Rachel Henderson, Randa Asa'd, Raymond Zich, Rebecca Lindell, Rebecca Rosenblatt, Remy Dou, Robert Hobbs, Robynne M. Lock, Rosemary Russ, Ryan Hazelton, Ryan J. Zamora, Ryan Sayer, Saif M. Ali, Samuel Luke Tunstall, Sarah B. McKagan, Scott Franklin, Sierra Decker, Simone Hyater-Adams, So Piten, Steven F. Wolf, Susan M. Fischer, Suzanne White Brahmia, Tharindu Jayasinghe, Tianlong Zu,

Tiffany-Rose Sikorski, Timothy J. Nokes-Malach, Tong Wan, Tor Ole Odden, Trevor I. Smith, Trevor S. Volkwyn, Tugba Yuksel, Tyler D. Scott, Valerie Otero, Vashti Sawtelle, Vincent P. Coletta, Wendy K. Adams, Westley James, William R. Evans, Xian Wu, Ying Cao, Yuri B. Piedrahita Uruena, Z. Yasemin Kalender, Zack Rowatt, and Zhongzhou Chen.

Finally, the Editors wish to express our special thanks to the PERC Coordination Committee chaired by Joel Corbo, who facilitated communications and coordinated logistics among multiple parties to make this year's PERC Proceedings a great success.

See you next summer in Washington, DC!

Lin Ding
Editor-in-Chief

Conference Overview: Mathematization and Physics Education Research

The number of publications that are focusing on mathematics in physics is increasing, and there are increasing connections between PER and the Research in Undergraduate Mathematics Education (RUME) community. As a result, we have chosen to highlight mathematization research at the 2017 PERC in Cincinnati. By mathematization, we refer to the spontaneous tendency to use mathematical concepts to quantify and make sense of the physical world. It is not about how well people can perform the procedures of mathematics. Rather, mathematization describes how people conceptualize the meaning of mathematics in the context of physics.

Expert-like mathematization in physics involves both a procedural and conceptual mastery of the prerequisite mathematics involved (Redish and Kuo, 2015; Thompson, 2011). Gray and Tall (1994) highlight this distinction, and refer to the target learning goal as *proceptual* understanding, in which *procedural* mastery and *conceptual* understanding coexist. When reasoning mathematically with physics quantities, many students become entrenched in a procedural approach. Some students reach a high level of procedural efficiency without much conceptual mathematical understanding, while other students develop greater mathematical flexibility. An achievement gap emerges between those who perform procedurally and those who develop greater flexibility. Gray and Tall refer to this gap in early math learning as the *proceptual divide*.

The proceptual divide is evident in physics courses, where success depends on having a proceptual understanding of both the prerequisite math and the learned physics. For example, Brahmia, Boudreaux, and Kanim (under review) report on obstacles that many calculus level students encounter using basic proportional reasoning when it involves physics quantities and real numbers, rather than everyday quantities and whole numbers. Rebello et al. (2007) observed that most introductory physics students approach symbol-rich physics problems that involve calculus or trigonometry as a procedure, framing their task as one of answermaking instead of sensemaking.

Organizers:

Steve Kanim, *New Mexico State University*

Suzanne White Brahmia, *University of Washington*

Michael Loverude, *California State University Fullerton*

John Thompson, *University of Maine*

The organizing committee of the PERC 2017 would like to express gratitude to the following individuals for their invaluable assistance in creating this conference:

The plenary speakers, Michael Oehrtmann and Megan Wawro; Lillian McDermott and Joe Redish; lunch speakers for Lillian and Joe, David Meltzer, Andrew Boudreaux, Ayush Gupta; Tim Fukawa-Connelly; Lyle Barbato and Bruce Mason with ComPADRE; Tiffany Hayes, Cerena Cantrell, Janet Lane, and Pearl Watson from AAPT; PERLOC for supporting award plaques; reviewers of juried talk proposals; and the PERC Proceedings Editors: Lin Ding, Adrienne Traxler, and Ying Cao.

PROGRAM

Wednesday, July 26, 2017

2:00pm **Bridging Plenary Talks – Event Center II**
Michael Oehrtmann
Quantitative reasoning and mathematical modeling in an introductory calculus sequence

Megan Wawro
Student Understanding and Symbolization of Eigentheory

3:30pm **Break, Poster Setup – 1st Floor Lobby**

4:00pm **First Timer / Undergraduate Poster Session – Event Center I**

5:00pm **Dinner (on your own) / Poster set up**

8:00pm **Contributed poster session (dessert, 2 groups, 45 min per group) – Event Center I**

Thursday, July 27, 2017

8:00am **Contributed poster session 2 (coffee) – Event Center I**

9:00am **Parallel Sessions Cluster I**

Juried Talks + Posters – IA – Meeting Room 6

Experimental Labs

Presenters: D. Andres, K. Ansell, L. Bao, M. D. Caballero, E. Etkina, K. Funkhouser, N. Holmes, D. Hu, K. Koenig, H. Lewandowski, L. Owens, K. Quinn, R. Rosenblatt, C. Ruggieri, V. Sawtelle, M. Selen, M. R. Stetzer, K. L. Van De Bogart, S. White Brahmia, C. Wieman, B. Wilcox, K. E. Wood, R. Zich, B. Zwickl

Talk Symposium – IB – Meeting Room 1

Contrasting Cases and Invention Activities in PER: Grounding students' understanding of conceptual and mathematical relations in physical contexts

Presenters: V. Alevin, D. M. Beardmore, A. Boudreaux, C. C. Chase, H. Connolly, N. R. Hallinen, S. E. Kanim, M. F. Keil, E. Kuo, T. K. Lê, M. Lamnina, C. M. Rebello, S. Salehi, D. L. Schwartz, J. T. Shemwell, M. R. Stetzer, B. A. Towle, S. White Brahmia, C. Wieman

Custom Format – IC – Meeting Room 2

Funny Physics: The Roles of Humor in Learning and Teaching Physics

Discussant: Rachel Scherr

Moderator: Luke Conlin

Presenters: L. Conlin, C. Gillespie Nyeggen, S. L. Li, E. Ronayne Sohr

Poster Symposium – ID – Meeting Room 3

Bridging Research and Practice in the Access Network

Moderator: Joel Corbo

Presenters: F. Amezcua, F. Davenport, S. Franklin, H. Jacks, M. Levy, A. Little, C. Mallares, K. Mardis, R. Mason, B. Pollard, G. M. Quan, K. Rainey, M. S. Sabella, N. Sanders, C. Turpen

Talk Symposium – IE – Meeting Room 4

Mathematical representations in quantum mechanics instruction

Moderator: John Thompson

Presenters: W. Christensen, E. Gire, G. Passante, E. Price, H. Sadaghiani, K. Watson, M. Wawro

10:45am

Parallel Sessions Cluster II

Juried Talks – IIA – Meeting Room 6

Juried Talks II

Presenters: L. Conlin, N. Finkelstein, J. Hoehn, M. Loverude

Talk Symposium – IIB – Meeting Room 5

Math for making sense or math for making answers?

Moderator: Natasha Holmes

Presenters: N. Hallinen, N. Holmes, E. Kuo, D. McPadden

Talk Symposium – IIC – Meeting Room 2

Mathematization in university level undergraduate physics courses

Moderator: Eleanor Sayre

Presenters: V. Dini, S. Franklin, B. Modir, N. Weliweriya, S. White Brahmia, B. Wilcox, D. Zohrabi Alae

Talk Symposium – IID – Meeting Room 4

Multiple perspectives on graduate admissions and diversity in physics

Moderator: Deepa Chari

Presenters: E. E.A. Brown, D. Chari, G. L. Cochran, T. Hodapp, A. Pershing, M. Plisch, G. Potvin, R. E. Scherr

Workshop – IIE – Meeting Room 3

"What Are You?" – Considerations and Best Practices in Operationalizing Identity through Demographic Variables

Presenters: J. J. Chini, J. Doyle, A. Little, B. Z. Roman, A. Traxler, C. Turpen

12:15pm

Lunch: Recognizing Pioneers of Mathematization in Physics

Education: Honoring Joe Redish and Lillian McDermott – Event Center II

1:30pm

Parallel Sessions Cluster III

Poster Symposium – IIIA – Meeting Room 3

Emerging Scholarship

Presenters: M. Dancy, A. Elby, P. Emigh, E. Gire, A. Gupta, M. Hull, E. Kuo, A. Phillips

Custom Format – IIIB – Meeting Room 4

Accessibility and Universal Design in Physics Education

Moderators: Jacquelyn J. Chini, Dimitri R. Dounas-Frazer, and Benjamin M. Zwickl

Presenters: J. J. Chini, S. Davis, W. James, E. B. Moore Perkins, K. K. Perkins, J. Principato, J. Schreffler, T. L. Smith, D. Spiecker, E. Vasquez III

Custom Format – IIIC – Meeting Room 2

People of Color Discussion Space

Facilitators: G. Cochran, A. Knaub

Talk Symposium – IIID – Meeting Room 1

Vectors and unit vectors in non-cartesian coordinate systems

Moderator: Michael Loverude

Presenters: W. Christensen, B. Farlow, B. E. Hinrichs, M. Loverude, B. Schermerhorn, J. Thompson, M. Vega

3:15pm

Closing and summary, including invited speaker panel – Event Center II

4:00pm

End of PERC

Introduction

Papers published in the 2017 Physics Education Research Conference Proceedings consist of two categories, juried papers and peer-reviewed papers.

Juried papers represent the juried talks that were new in the 2017 PERC Proceedings format. These papers describe mature research projects and undergo double-blind peer review. Twenty-four juried talk proposals were submitted, of which five were accepted.

Peer reviewed papers are written products of any presentation other than the plenary or juried talks. Each paper in this category undergoes a rigorous peer review process in order to be published in the Proceedings. This year saw 156 submitted manuscripts, of which 115 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.