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Sabella
Henderson
Singh

2009 PHYSICS EDUCATION RESEARCH CONFERENCE

1179

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Ann Arbor, MI 29–30 July 2009

EDITORS
Mel Sabella
Charles Henderson
Chandralekha Singh

AIP CONFERENCE PROCEEDINGS ■ 1179

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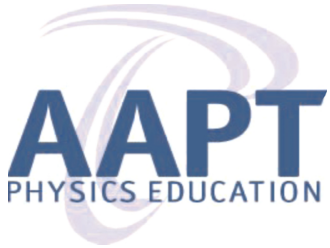

EDITORS

Mel Sabella
Chicago State University
Chicago, Illinois

Charles Henderson
Western Michigan University
Kalamazoo, Michigan

Chandralekha Singh
University of Pittsburgh
Pittsburgh, Pennsylvania

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Editors:

Mel Sabella
Chemistry and Physics Department
Chicago State University
309 Science Building
9501 South King Dr.
Chicago, IL 60628-1598
USA
E-mail: msabella@csu.edu

Charles Henderson
Physics Department
Western Michigan University
1903 West Michigan Avenue
Kalamazoo, MI 49008-5252
USA
E-mail: charles.henderson@wmich.edu

Chandralekha Singh
Physics & Astronomy Department
University of Pittsburgh
218A Allen Hall
3941 O'Hara Street
Pittsburgh, PA, 15260
USA
E-mail: singh@phyast.pitt.edu

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PEER REVIEWED PAPERS

PREFACE

The theme of the 2009 Physics Education Research Conference was *Physics Education Research across Paradigms*. Four leading researchers who conduct learning research from different perspectives were invited to present their work and interact with the Physics Education Research (PER) community. This was an opportunity for the PER community to examine and discuss the variety of traditions and frameworks relevant to the study of student learning of physics. Understanding and being able to apply different frameworks is crucial in that it allows us to become more productive and flexible in our research. Following this preface you will find a short paper written by the conference organizers that provides a description of the 2009 theme as well as how the theme fits with our work in PER.

In addition to papers by the featured presenters, many papers in this volume by members of the PER community also address the issue of research methodologies and frameworks. The remainder of the papers represent the diversity of directions within PER and help this volume fulfill its purpose of providing an annual snapshot of the field. The Editors thank the conference organizers, Dr. Tetyana Antimirova, Dr. Nathaniel Lasry, and Dr. Marina Milner-Bolotin, as well as the Physics Education Research Leadership and Organizing Council (PERLOC) for putting together a successful and well-run meeting.

This is the second year that the Proceedings has used an online submission process for contributed papers and referee reports. Several modifications helped to make the system more efficient and user friendly this year. We wish to thank Lyle Barbato and Bruce Mason of comPADRE.org for their continued work on the system.

Last but not least, this volume owes its existence to the referees, who volunteer their time and expertise to help improve the quality of the papers published in the Proceedings. This year we had 114 reviewers who reviewed the 79 papers submitted to the Peer Reviewed Section. The Editors thank: W. Adams, H. Alhadlaq, P. Allen, B. Ambrose, T. Antimirova, G. Aubrecht, C. Baily, L. Barbato, A. Barrantes, T. Bartiromo, J. Bartley, K. Black, J. Blue, E. Brewe, D. Briggs, A. Carmichael, J. Carvalho, E. Charles, S. Chasteen, J. Chini, W. Christensen, G. Cochran, V. Coletta, E. Corpuz, C. Crouch, K. Cummings, M. Dancy, D. Demaree, L. Ding, J. Docktor, A. Dominguez, M. Dubson, D. Dykstra, E. Etkina, N. Finkelstein, T. Foster, N. Gillespie, S. Goldhaber, K. Gray, D. Hammer, D. Harlow, K. Harper, J. Hawkins, A. Heckler, K. Heller, C. Henderson, B. Hinrichs, L. Hsu, H. Iverson, N. Juma, D. Kaltakci, P. Kohl, L. Kost, L. Kramer, H. V. Kuo, N. Lasry, S. Li, S. Lin, M. Loverude, S. Martinuk, F. Mateycik, L. Mayhew, D. McBride, L. McCullough, M. Milner - Bolotin, A. Moyer, S. Murphy, T. Mzoughi, C. Nakamura, D. Nguyen, V. Otero, A. Paulson, A. Pawl, K. Perkins, J. Phillips, N. Podolefsky, S. Pollock, E. Price, D. Pritchard, S. Ramlo, N. Reay, S. Rebello, R. Rosenblatt, D. Rosengrant, M. Villasenor, M. Sabella, H. Sadaghiani, J. Saul, N. Sawadthaisong, V. Sawtelle, E. Sayre, R. Scherr, B. Schmitt, D. Schuster, V. Shekoyan, C. Singh, B. Spike, R. Talbot, J. Thompson, C. Thomson, C. Turpen, A. Undreiu, D. Van Domelen, D. Wagner, W. Wampler, A. Warren, J. Watkins, C. Wieman, V. Winters, M. Wittmann, E. Yerushalmi, G. Zavala, G. Zhu, D. Zollman.

See you next summer in Portland!

Charles Henderson
Outgoing Editor

INTRODUCTION

PHYSICS EDUCATION RESEARCH ACROSS PARADIGMS

N LASRY, M MILNER-BOLOTIN AND T ANTIMIROVA

Did you ever wonder how neurologists, psychologists, sociologists or anthropologists study learning by looking at fundamentally different things? Can a similar 'LEARNING' phenomenology be present in neural function, cognitive processes, social participation or culture mediation?

Those interested in understanding learning from more than one perspective usually encounter the acrimonious relationship between researchers working in different paradigms. This led UC Berkeley Mathematician and former AERA president Alan Schoenfeld to claim in his 1999 presidential address [1]:

"*…there is still, in large measure, a schism between 'fundamentally cognitive' and 'fundamentally social' studies of human thought and action*".

PER is an effervescent and unique field of research that implicitly resides at a crossroad between diverse traditions and frameworks used to study learning: cognitive constructs, social and cultural dynamics and increasingly neural processes. Although individual PER researchers work within preferred paradigms and methodologies, as a whole PER has not been exclusive in its commitment to a single paradigm or methodology.

The theme of PERC 2009 was "Physics Education Research across Paradigms" and it featured leading researchers in cognitive psychology, in social and cultural studies and in neuroscience: Andrea diSessa, Kevin Dunbar, Michael Posner and Anna Sfard. These scholars shed light on how cutting-edge research on learning is conducted within each framework and how different research methodologies apply to PER. In the remainder of this introduction we present our view of the importance of bridging paradigms that led us to choose this issue as the theme of PERC 2009.

PARADIGMS AS SYSTEM LEVELS

One way to think about the different paradigms is using Newell's idea of system levels [2]. In a system with many levels, processes on one level are carried out by the level just below it. Thus, system levels are hierarchical in that they differ in length and time scales. This is indeed the case for learning paradigms. For instance, neural processes occur in micro to milliseconds whereas cognitive processes occur in hundreds of milliseconds to minutes and social processes occur in tens of seconds to hours or days. This scaling can be also applied to length scales with the size of neurons on one end and of social groups on the other. The figure below presents each paradigm on an axis of increasing length/time:

FIGURE 1. Different disciplines and paradigms used to study learning on a scale of increasing size and process-time.

CHOOSING A PERSPECTIVE?

There is a disadvantage of having such eloquent speakers talk with fervor about learning using research perspectives that differ so markedly. One is left asking: what is ***the*** best way to study learning?

The simple answer, and hopefully the take home message from PERC 2009, is: you should not have to choose! How then might one reconcile the differences between these paradigms? One possibility is using an organizing metaphor which we will refer to as the Cole-Suvorov metaphor [3].

BRIDGING PARADIGMS

Each paradigm brings something that other paradigms cannot account for. Taken alone, each paradigm seems insufficient to understand LEARNING. How then can these paradigms be bridged?

To bridge paradigms, we turn to the work of a Russian psychologist Suvorov on the "formation of representations in blind-deaf children" as described by Michael Cole [3]. To Suvorov, being able to make meaning of the world requires the ability to distance oneself and then return to it. Applying this metaphor to deaf-blind children, Suvorov proposed that children could not appropriately construct their reality because they are not able to distance themselves from it. Michael Cole notes [3] that deaf-blind children cannot:

> *"manage to separate from the world as [these children's] main distance sensors are gone. If you can't separate from the world, you can't understand it"*

Cole presents a "strong analogy" on the neurological level presenting results on image formation on the retina. Two-week old infants construct an image by moving away and towards the point of highest contrast, suggesting a "philogenetic" constraint on the process. The acquisition of an image on the retina requires "saccadic" eye motion. Indeed, word formation in reading adults is also achieved with saccades. That is, as you read these lines, to make meaning out of these lines cognitively speaking, your eyes must saccade back and forth. You do not read these words in perfect linear sequence. Furthermore, Cole continues with the example of college students deciphering constituents of a monogram (discoordination of the image, together and apart) showing that cultural constraints exist on this process as well. What happens if this 'towards and away' process is prevented?

If an image is stabilized (i.e. no saccades), habituation ensues: The object disappears and the field of vision becomes grey. Saccades bear a striking similarity to Suvorov's metaphor of being able to construct reality by moving away and then back to it.

Independent of scale, the Cole-Suvorov metaphor can be summarized as follows:

- Observing of an object and making meaning requires 'saccadic' motion: a separation and return to the object.
- Corollary: Stabilizing the object by failing to separate and return to it (i.e. no 'saccades') results in image disappearance and the field becomes grey.

What does all this have to do with bridging paradigms?

This metaphor becomes ideal for the bridging of paradigms if taken up one level of abstraction. Suppose that the image we are trying to form is that of LEARNING. A thorough image of the process should involve a shift in the distance to the observed object. That is, to construct an accurate image of LEARNING requires a dynamic observation from up close to far away: From the micro-scale neuro-cognitive processes to the macro-scale socio-cultural processes *and back*.

Conversely, choosing a single position (i.e. a single scale or paradigm) is analogous to stabilizing the image: the object disappears and the FIELD [education?] becomes grey! The key to the construction of an accurate image of LEARNING is the saccade between paradigms. Thus, it is not that one shouldn't have to choose a paradigm but rather that choosing a single paradigm is incomplete… The remaining question is: How does this apply to PER?

Let us suppose that a PER study is interested in expertise. This could be done by looking at undergraduate students, graduate students and faculty. Another possibility would be looking at the evolution of pedagogical content knowledge (PCK) [4] in pre-service physics teachers' as they become experienced in-service physics teachers and recognized expert physics teachers. The socio-cultural lens would focus on how the novices -as a group- enter the teaching community from its periphery, how novices interact with mentors and how they progressively become more central participants in their community [5]. The cognitive lens would focus on a conceptual trajectory (physics concepts or PCK). That is, how the novices progressively change their conceptions (either in physics or in how students learn physics) towards more expert views. A neurocognitive approach could seek to correlate one's expertise with activity in different neural loci. In physics, one would expect experts to activate multiple modalities such as verbal, mathematical, visuo-spatial and kinesthetic representations which all have established neural loci [6]. With respect to physics teaching one would also expect activity in the medial frontal cortex, a part of the brain involved in social cognition [7]. Following a question asked to Posner during the conference: it would be possible to use Trans-cranial Magnetic Stimulation on a locus correlated with expertise. This would temporarily inhibit activity in that locus. One could then determine the effect of that locus on (the novice-teacher's or novice physicist's) expertise. For instance, what would the effect of temporarily inhibiting the medial frontal cortex be on a teacher's PCK and how would this transpire in a group setting? Conversely, how do variations in group dynamics affect one's PCK resources and would differences be apparent in neurocognitive activity. Taken together, each lens would complement each other allowing for an unprecedented kind of triangulation.

Looking at all lenses simultaneously could have another advantage beyond triangulation (i.e. where each lens adds information not available on other scales). An intriguing possibility is that these pictures do not provide complementary information but rather self-similar information: Each being a pattern similar in structure differing only in scale. For instance, social networks (such as those pre-service teachers or novice physicists evolve through) bear an uncanny similarity in structure to semantic networks on the cognitive level or to neural networks [8]. Thus, instead of looking at the different information each scale provides, the focus would be on resolving the structure on one scale to determine whether one can expect to find the same structure on other scales.

CONCLUSION

Learning is studied in many disciplines where different paradigms are used to conduct research. As an adolescent field with no long history of using a single tradition, method or paradigm, PER may be the ideal field to experiment on the bridging of paradigms, something Schoenfeld had identified as one of the 10 issues the educational community should strive to address in the 21st century [1]. We suggest that it is not necessary to choose a single paradigm to study LEARNING. In fact, we suggest that choosing a single paradigm may be counter-productive and lead our field into the grey. Instead, we should consider looking at LEARNING dynamically by analyzing it as a process by moving across scales. That is, learning phenomena should be studied using saccades from the neuro-cognitive scale to the socio-cultural scale and back.

As organizers of PERC 2009, we chose this theme inspired by its exciting possibilities and hope that the sessions on the different paradigms and their methods have been stimulating and that you will consider neuro-cognitive, cognitive psychology and socio-cultural lenses in your future endeavors.

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PERC 2009 Program

Time	Session	Location
Wednesday, July 29th		
3:30 pm – 5:30 pm	**PER Bridging Session**: Three presentations by invited speakers and a discussion	Dennison 170
6:00 pm – 10:00 pm	**Banquet & Contributed Poster Session Part I:** all posters are displayed (odd - numbered posters are discussed from 8:00 pm – 9:00 pm and even-numbered posters are discussed from 9:00 pm – 10:00 pm.)	Michigan League Ballroom
Thursday, July 30th		
8:30 am – 9:45 am	**Special Session 1**: Invited Workshops; Targeted Poster Sessions, Round Table Discussions	Dana 1024, 1028 Dennison 110, 120, 130
9:45 am – 10:00 am	Coffee Break	Michigan League Concourse
10:00 am – 10:55 am	**Poster Session Part II:** all posters are displayed (odd - numbered posters discussed from 10:00 am – 10:25 am; even-numbered posters discussed from 10:30 am – 10:55 am.)	Michigan League - Hussey and Vandenbur
11:00 am – 12:15 pm	**Special Invited Speaker Panel**	Dennison 170
12:15 pm – 1:30 pm	**Lunch**, Announcements, etc.	Michigan League Concourse (Michigan Room)
1:30 pm – 2:30 pm	**Special Session 2:** Invited Workshops; Targeted Poster Sessions, Round Table Discussions	Dana 1024, 1028 Dennison 110, 120, 130
2:30 pm – 2:45 pm	Coffee Break	Michigan League Concourse
2:45 pm – 3:45 pm	**Special Session 3:** Invited Workshops; Targeted Poster Sessions, Round Table Discussions	Dana 1024, 1028 Dennison 110,120, 130
4:00 pm – 5:30 pm	**Round Table Report:** Conference summary and Q&A session.	Dennison 170

Wednesday, July 29th: Detailed Schedule

3:30 pm - 5:30 pm **PER Bridging Session (Dennison 170)**
Presiding: Lasry
3:30 pm

Bridging Cognitive and Neural Aspects of Classroom Learning
Michael Posner, Sackler Institute for Developmental Psychobiology, mposner@uoregon.edu

Causality in Pieces: The Construction of Causal Schemes
Andrea diSessa, University of California at Berkeley, adisessa@soe.berkeley.edu

Moving between Discourses: From Learning-as-Acquisition to Learning-as-Participation
Anna Sfard, Michigan State University, sfard@netvision.net.il

Questions to the invited speakers

6:00 pm - 10:00 pm **Banquet and Poster Session - *ticket required***
Presiding: Milner-Bolotin

6:00pm (Michigan League Ballroom)
The Biology of Physics: What the Brain Reveals about our Understanding of the Physical World
Kevin Niall Dunbar, University of Toronto, dunbar@utsc.utoronto.ca

8:00pm, Contributed Poster Session PART I, Cash Bar*
Posters will remain on display for the duration of the conference

Thursday, July 30th: Detailed Schedule

8:30 am – 9:45 am

Special Session 1

Invited Workshops (W), Targeted Poster Sessions (TP), Roundtable Discussions (RTD)

PART I

(W1) Methods and Experimental Designs in Cognitive Studies (Dennison 110)

Jose P. Mestre, University of Illinois, mestre@uiuc.edu

Michael Posner, University of Oregon, mposner@uoregon.edu

(TP-A) Cognitive Issues in Developing Curriculum for Upper-Level Physics Courses (Dennison 120)

Chandralekha Singh, University of Pittsburgh, Department of Physics, University of Pittsburgh, clsingh@pitt.edu

(TP-B) Foundations of Course Reform for Introductory Physics (Dennison 130)

David E. Pritchard, MIT, dpritch@mit.edu
Analia Barrantes, MIT , analiab@mit.edu
Andrew Pawl, MIT, aepawl@mit.edu
Brian Belland, Utah State University , brian.belland@usu.edu

(TP-C) Negotiating Meaning: Rethinking and Re-Interpreting Knowledge (Dana 1024)

Edit Yerushalmi, *edit.yerushalmi@weizmann.ac.il*

(W-2) Qualitative Research Methods (Dana 1028)

Valerie K. Otero, University of Colorado at Boulder, valerie.otero@colorado.edu
Kara Gray, University of Colorado at Boulder

9:45 am– **Break (15 minutes)**

10:00 am – 10:55 am **Poster Session PART II. Refreshments provided (Michigan League – Hussey & Vandenburg).** All posters are displayed (odd - numbered posters discussed from 10:00 am – 10:25 am; even-numbered posters discussed from 10:30 am – 10:55 am.

11:00 am – 12:15 pm **Special Invited Speaker Panel (Dennison 170)**

Presiding: Antimirova, Lasry, Milner

12:15 pm – 1:25 pm **Luncheon (Michigan Room, Michigan League Concourse)**

Announcements, etc.

1:30 pm – 2:30 pm **Special Session 2**

Invited Workshops (W), Targeted Poster Sessions (TP), Roundtable Discussions (RTD)

PART II

(TP-B) Foundations of Course Reform for Introductory Physics (Dennison 130)

David E. Pritchard, MIT, dpritch@mit.edu; Analia Barrantes, MIT , analiab@mit.edu

Andrew Pawl, MIT, aepawl@mit.edu; Brian Belland, Utah State University , brian.belland@usu.edu

(TP-C) Negotiating Meaning: Rethinking and Re-Interpreting Knowledge (Dana 1024)

Edit Yerushalmi, *edit.yerushalmi@weizmann.ac.il*

(TP -D) Broadening Our Lens: Socio-Cultural Perspectives in PER (Part I: artifacts and mediation) (Dennison 110)

Noah Finkelstein,University of Colorado at Boulder, noah.finkelstein@colorado.edu
Chandra Turpen,University of Colorado at Boulder

(RTD-2) Cognition of an Expert Tackling an Unfamiliar Conceptual Physics Problem (Dennison 120)

David Schuster, Western Michigan University, david.schuster@wmich.edu
Adriana Undreiu, University of Virginia's College at Wise, Department of Natural Sciences

2:30 pm **Coffee Break (15 minutes): Refreshments provided (Michigan League Concourse)**

2:45pm – 3:45pm **Special Session 3**

Invited Workshops (W), Targeted Poster Sessions (TP), Roundtable Discussions (RTD)

PART III

(TP-A) Cognitive Issues in Developing Curriculum for Upper-Level Physics Courses (Dennison 120)

Chandralekha Singh, University of Pittsburgh, Department of Physics, University of Pittsburgh, clsingh@pitt.edu

(TP-E) Broadening Our Lens: Socio-Cultural Perspectives in PER (Part II: communities & social interaction) (Dennison 110)

Noah Finkelstein, University of Colorado at Boulder, Department of Physics, noah.finkelstein@colorado.edu
Chandra Turpen, University of Colorado

(RTD-1) Where do the Student Conceptions Come from? Light and Optics Case (Dennison 130)

Derya Kaltakci, Physics Education Group, Department of Physics, University of Washington, kaderya@metu.edu.tr Ali Eryilmaz, eryilmaz@metu.edu.tr **CANCELLED**

4:00pm – 5:30pm **Round Table Report (Dennison 170)**
Presiding: Antimirova, Lasry

Discussants & plenary speakers summarize the results of the RT sessions, posters and the entire conference; audience questions are welcome.

Led by round table speakers, targeted poster session discussants, and invited speakers