PHYSICS EDUCATION RESEARCH CONFERENCE

"*Transfer of Learning*"

August 4-5, 2004
California State University, Sacramento

PROGRAM

http://web.phys.ksu.edu/perc2004/

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About PERC

Description: The Physics Education Research Conference (PERC) provides an opportunity for those in the field of physics education research and allied fields to share their research, obtain feedback, explore diverse perspectives and discuss issues relevant to the community. Various session formats afford the opportunity for maximum interaction. The focus at PERC is on feedback and discussion with others engaged in physics education research, rather than on dissemination.

Theme: This year's theme is "***Transfer of Learning***" Participants will explore diverse perspectives on the meaning and implications of transfer of knowledge and learning as it pertains to their research. While all of the presentations and activities at PERC will not explicitly focus on transfer of learning *per se*, participants are urged to reflect and discuss how various perspectives on transfer of learning can inform their own research as well as the overarching agenda of the field. A variety of session formats will provide opportunities for multiple perspectives in our discussion of transfer of learning.

Registration: The registration form for the 129th National Meeting of the American Association of Physics Teachers (AAPT) includes a line to register for PERC 2004. The cost for registration is $65 and includes lunch and a copy of the Conference Proceedings.

The PERC dinner on Thursday evening is ticketed separately. Please purchase dinner tickets and register for the PERC in advance since on-site registration is limited.

Participation: A variety of session formats are available to participants in PERC 2004. These include Invited Talks & Panel Discussions, Targeted Poster Sessions, Data Analysis Consultation Sessions, Workshops, Roundtable Discussions and Contributed Posters.

Previous Physics Education Research Conferences

- **2003 -** "The Practice of Analysis as a Window on Theory," Madison, WI
- **2002 -** "Alternative Approaches to Assessment in Physics Teaching and Research in Physics Learning," Boise State University, Boise, ID
- **2001 -** "Research at the Interfaces," Rochester, NY
- **2000 -** "Teacher Education," University of Guelph, Canada
- **1999 -** "The Underlying Assumptions of Physics Education Research," Trinity University, San Antonio, TX
- **1998 -** University of Nebraska, Lincoln, NE
- **1997 -** University of Denver, Denver, CO

Schedule

WEDNESDAY, AUGUST 4

When	Where	What
4:00 - 6:00	Union Redwood	AAPT/PERC Bridging Session
		4:00 **Is Transfer Ubiquitous or Rare? New paradigms for studying transfer**, *Jose Mestre* (University of Massachusetts, Amherst)
		4:30 **Assessing Transfer of Conceptual Understanding**, *Karen Cummings* (Southern Connecticut State University)
		5:00 **Measuring the Transfer of Mathematical Skills**, *Manjula Sharma* (University of Sydney, Australia)
		5:30 Panel Discussion, Discussant: *To be announced*
6:00 - 8:00	---	Free Time for Contributed Poster Set-Up & Dinner (On Your Own)
8:00 - 10:00	Ballroom II	**Contributed Poster Session** (Dessert, Coffee & Full cash bar) *Posters will remain up all day through Thursday, August 5*
9:00 - 10:00	Lobby Suite	**Round Table Discussion** (Parallel Sessions)

THURSDAY, AUGUST 5

When	Where	What
8:00 - 8:15	Redwood	Orientation
8:15 - 9:45		Parallel **Workshops** & **Targeted Poster** Sessions – I
	Delta Suite	Workshop W-A **Getting Articles into Journals**, *Robert Beichner* (North Carolina State University)
	Auburn Room	Workshop W-B: **The Physics Portal: Building a Self-Sustaining Internet-based Education Network**, *David Hestenes* (Arizona State University), *Bernard Haisch* (ManyOne Network)
	Folsom Room	Workshop W-C: **Laboratory Math & Science for Cognitive Development -- Dealing with the Real Level of our Physics Students,** *Jerome Epstein* (Polytechnic University)
	Summit Room	Targeted Poster Session TP-A **Challenges for the PER Community: Exploration of Common Assumptions, Open Questions & Current Controversies**, Organizer: *Paula Heron* (University of Washington)
	California Suite	Targeted Poster Session TP-B: **Beyond Student Transfer: Graduate, Postdoc and Faculty Development & The Road to Sustainable, Scalable Inclusion of PER** Organizers: *Noah Finkelstein* (Univ. of Colorado), *Melissa Dancy* (Univ. of NC)
	Lobby Suite	Targeted Poster Session TP-C: **Going Up? -- Learning Transfer Among Students in Upper-Level Physics Courses**, Organizer: *Chandralekha Singh* (Univ. of Pittsburgh), *Bradley Ambrose* (Grand Valley State Univ.)
9:45 - 10:15	Ballroom II	Break (Refreshments provided)
10:15 - 12:15	Union Redwood Room	**Invited Talks & Panel Discussion**
		10:15 **What Coordination has to say About Transfer**, *Andrea diSessa* (University of California, Berkeley)
		10:45 **Innovation and Efficiency in Transfer**, *Daniel Schwartz* (Stanford University)
		11:15 **When You Don't See It -- Why Not,** *Zbigniew Dziembowski* (Temple Univ.)
		11:45 Panel Discussion, Discussant: *Jose Mestre* (University of Mass., Amherst)

THURDSAY, AUGUST 5 (Continued)

When	Where	What
12:15 - 1:45	Ballroom III	Luncheon Banquet & Talk: *Duncan McBride*, NSF
1:45 - 3:15		Parallel **Workshops** & **Targeted Poster** Sessions – II
	Delta Suite	Workshop W-A: **Getting Articles into Journals**, *Robert Beichner* (North Carolina State University)
	Folsom Room	Workshop W-D: **Transferring PER Results from the Domain of the Researcher to the Domain of the Practitioner**, *Kenneth Heller* (University of Minnesota)
	Auburn Room	Workshop W-B: **The Physics Portal: Building a Self-Sustaining Internet-based Education Network**, *David Hestenes* (Arizona State University), *Bernard Haisch* (ManyOne Network)
	Lobby Suite	Targeted Poster Session TP-C: **Going Up? -- Learning Transfer Among Students in Upper-Level Physics Courses**, Organizer: *Chandralekha Singh (*Univ. of Pittsburgh), *Bradley Ambrose* (Grand Valley State Univ.)
	Orchard II & III	Targeted Poster Session TP-D: **Issues in Studying Transfer of Problem Solving Skills**, Organizers: *Kathleen A. Harper* (The Ohio State Univ.), *Thomas Foster* (Southern Illinois Univ. - Edwardsville), *David P. Maloney* (Indiana Univ. Purdue Univ. Fort Wayne)
	Forest Suite	Targeted Poster Session TP-E: **Determining Transfer of Learning with Longitudinal Studies Using Grade & Demographic Data on Individual Students**, Organizer: *Wendell Potter* (University of California, Davis)
3:15 - 3:45	Ballroom II	Break (Refreshments provided)
3:45 - 5:15		Parallel **Workshops** & **Targeted Poster** Sessions - III
	Folsom Room	Workshop W-D: **Transferring PER Results from the Domain of the Researcher to the Domain of the Practitioner**, *Kenneth Heller* (University of Minnesota)
	Auburn Room	Workshop W-C: **Laboratory Math & Science for Cognitive Development -- Dealing with the Real Level of our Physics Students**, *Jerome Epstein* (Polytechnic Univ.)
	Summit Room	Targeted Poster Session TP-A: **Challenges for the PER Community: Exploration of Common Assumptions, Open Questions & Current Controversies** Organizer: *Paula Heron* (University of Washington)
	California Suite	Targeted Poster Session TP-B: **Beyond Student Transfer: Graduate, Postdoc, and Faculty Development & The Road to Sustainable, Scalable Inclusion of PER** Organizers: *Noah Finkelstein* (Univ. of Colorado), *Melissa Dancy* (Univ. of North Carolina)
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	Forest Suite	Targeted Poster Session TP-E: **Determining Transfer of Learning with Longitudinal Studies Using Grade & Demographic Data on Individual Students** Organizer: *Wendell Potter* (University of California, Davis)
5:15 - 6:30	---	Free Time
6:30 - 8:00	Ballroom III	Dinner Banquet (Ticket Needed)

AAPT/PERC Bridging Session

Wednesday, August 4
4:00 pm - 6:00 pm
Redwood Room
Presider: *N. Sanjay Rebello*, Kansas State University

4:00 pm **Is Transfer Ubiquitous or Rare? New Paradigms for Studying Transfer**

Jose P. Mestre, University of Massachusetts, Amherst

The term transfer is used in the cognitive literature to mean the application of learning acquired in one context to another context. Studies commonly show lack of transfer, leading some to question whether it happens at all. Others argue that transfer is ubiquitous (e.g., you are transferring your knowledge now to understand this abstract). I will discuss an emerging view of transfer that, rather than focusing on whether some body of knowledge is applied (or not) wholesale to a novel context, focuses on activation and application of knowledge pieces. This view shifts the emphasis from asking "did transfer happen?" to asking questions such as "what knowledge is activated and how does it depend on context?", "what is the nature and dynamic of the activation process, and how reliable is it?" I will provide some examples of the kinds of insights that ensue when transfer studies are analyzed from this new perspective and discuss implications for PER.

Work supported by NSF grant REC-010677.

4:30 pm **Assessing Transfer of Conceptual Understanding**

Karen Cummings, Southern Connecticut State University

A project is underway at Rensselaer Polytechnic Institute in which tools and techniques are being developed to assess the transfer of conceptual understanding developed in introductory physics and calculus courses to higher level engineering courses. This project, which is funded under the NSF-CCLI Assessing Student Achievement program, will be described in this talk. The tools under development will be presented as will preliminary data sets. The research on transfer of understanding that informed the project design will be discussed as well.

5:00 pm **Measuring the Transfer of Mathematical Skills**

Manjula Sharma, University of Sydney, Australia

The development of numeracy and mathematical skills in university science students is essential for success in their studies and future careers. However, anecdotal evidence indicates that a significant number of students demonstrate inadequate mathematical skills when solving discipline specific problems requiring basic mathematics. To better understand this issue, a team of researchers from the University of Sydney have developed and trialed an instrument for measuring the transfer of mathematical skills and knowledge. In this presentation I will present the complex pattern of transfer emerging from our investigations. I will also discuss questions that have arisen and implications for PER.

Project supported by a SCIFER grant at the University of Sydney.

Team Members: Sandra Britton (School of Mathematics and Statistics), Peter New (School of Microbiology), David Yardley (School of Mathematics and Statistics), Andrew Roberts (School of Physics), Science Faculty Education Research Group (SciFER), Faculty of Science, University of Sydney.

5:30 pm **Panel Discussion**

Invited Talks & Panel Discussion

Thursday, August 5
10:15 am - 12:15 pm
Redwood Room
Master of Ceremonies: *Jose P. Mestre*, University of Massachusetts, Amherst

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10:15 am **What Coordination Has to Say about Transfer***

Andrea diSessa, University of California, Berkeley

I will build a perspective on the issue of transfer based out of an evolving theory of conceptual development, called coordination class theory. Coordination class theory defines a certain class of concepts, and analyzes their construction as a gradually assembled "complex system." Coordination classes entail a particular set of problems for learners, which, in turn, provides a perspective on when transfer happens, when it does not, and how it can be prepared for. Coordination classes emphasize the possibility that different knowledge (different "concept projections") may be used to "implement" the same concept in different situations. In view of coordination class theory, some types of transfer (Class C transfer, which I will define) are ubiquitous, although difficult to see, especially if normative or even stable competence is the measure. Other types of transfer (Class A transfer), counter to the apparent assumption of much transfer literature, should not be expected to happen without extensive learning, probably involving many contexts. If a coordination class is at issue in Class A transfer, definite expectations about loci of difficulty exist. Finally, when transfer happens, it may not happen by virtue of highly abstract and therefore general schemata (knowledge elements). Instead, it may happen by the accumulation and coordination of much more specific, "concrete" knowledge, which is useful in particular situations. This last provides a fairly radical reformulation of one of the most generally accepted assumptions of the transfer literature.

*Based on a paper by the same name by A. diSessa and J. Wagner, to appear in J. P. Mestre (Ed.), *Transfer of learning: Research and perspectives* (Working Title). Greenwich, CT: Information Age Publishing

10:45 am **Innovation and Efficiency in Transfer**

Daniel Schwartz, Stanford University

The transfer literature includes a variety of seemingly conflicting perspectives. Some argue that transfer is rare; others argue that transfer is ubiquitous; still others worry that transfer is an unworkable concept. Is the transfer literature filled with inherently contradictory claims, or is there a framework that can help illuminate how and why the varied positions on transfer are each pieces of the truth that can be reconciled through a broader theoretical foundation? I will argue for the latter by (a) rethinking the classic definition of transfer and show how it tends to misdiagnose important forms of knowing; (b) differentiate "transferring in" to situations from "transferring out" of them; (c) discuss studies that show that new ways to think about transferring "in" and "out" can reveal advantages of interactive instructional techniques that remain hidden from more traditional measures; and (d) propose a tentative learning and performance space that differentiates two dimensions of transfer -- innovation and efficiency -- and provide an example of what research on optimal trajectories through this space might look like.

11:15 am **Transfer of Learning: When You Don't See It, Why Not?**

Zbigniew Dziembowski, Temple University

Transfer of learning plays a pivotal role in education, yet there are some noteworthy failures to observe transfer. In this talk I will review failed attempts to demonstrate the existence and effects of transfer, specifically 'far transfer.' I will then discuss recent advances in our understanding when transfer does not occur and why, focusing on schematic and analogical transfer of mathematical problem solving procedures acquired through physical science instruction.

11:45 am **Panel Discussion**

Targeted Poster Session: TP-A

Challenges for the PER Community: An Exploration of Common Assumptions, Open Questions, and Current Controversies

Thursday, August 5
8:15 – 9:45 & 3:45 – 5:15
Summit Room

Paula Heron (pheron@dirac.phys.washington.edu), Univ. of Washington

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Goal: In this Targeted Poster Session, we will each identify specific common assumptions, open questions, or current controversies and argue the need for their illumination through research. We will challenge the community to tackle these issues and propose some initial steps. Participants in the session will be invited to refine and/or redirect these challenges, and pose additional ones of their own. The goal will be to stimulate research on some issues of importance for the field.

Individual Poster Abstracts

TP-A1 **Macroscopic Observations and Microscopic Models: What do Students *Really* Learn from Computer Simulations?**

Paula Heron (pheron@dirac.phys.washington. edu), University of Washington

In 2000, Richard Steinberg published an article with the provocative title "Computers in teaching science: To simulate or not to simulate?" Steinberg had investigated student learning of air resistance with and without a computer simulation. Among his goals was to assess the effect of simulated experiments on student understanding of the nature of science. Unfortunately, there are very few examples of research of this sort. The enormous effort being devoted to the development and dissemination of increasingly sophisticated simulations has not been accompanied by a similarly vigorous attempt to understand their effects on student understanding, either of the relevant concepts and principles or of the nature of scientific models. I will argue that the implications of computer simulations for students' epistemological development are in need of serious, systematic investigation. In particular, we need to understand what to do to ensure that simulations involving microscopic particles and processes enlighten, rather than mislead, students about the nature of scientific models. This kind of research is needed to provide guidance on the use of simulations in courses that have as their goals helping students develop increasingly sophisticated views of the scientific enterprise as well as of scientific concepts.

TP-A2 **How Do You Hit a Moving Target? Addressing the Dynamics of Students' Thinking**

David Meltzer (dem@iastate.edu), Iowa State University

From the standpoint both of research and instruction, the variable and dynamic nature of students' thought processes poses a significant challenge to PER. It is difficult merely to assess and characterize the diverse phases of students' thinking as they gain and express understanding of a concept. (We might call this the "kinematics" of students' thought processes.) Much harder still is uncovering the various factors (instructional method, student characteristics, etc.) that influence and determine the trajectory of students' thinking, and deciphering the mutual interaction of these factors. (We could call this the "dynamics" of students' thinking.) I will outline some of the initial work that has been done along these lines by various researchers, and I will identify some directions for future research that I think might be fruitful for workers in PER.

TP-A3 **Synthesis in PER: How Does It All Fit Together?**

Edward F. Redish (redish@umd.edu), University of Maryland

We often say that as physics education researchers, we are applying the methods of science to help up understand how our students learn and do not learn physics. Often, however, our "application of the scientific method" is restricted to observing what our students do and trying to correlate their learning with instructional changes that seem, intuitively, to make sense to us. It is more like "seat-of-the-pants" engineering than like physics; more like Edison's search for the proper filament for a light bulb than like the current attempt to understand spintronics in order to (eventually) build a better microchip. In true science research, our experiment and theory perform an intricate dance, with theory at one time taking the lead and suggesting experiments, at another time with experiment taking the lead and producing results that demand new theoretical explanations. Very little of what we do in PER resembles this complex and productive interplay of theory and experiment. The big problem seems to be the lack of a serious theoretical frame. Without a serious theoretical frame we are unable to synthesize, unable to generate reliable predictions in situations we haven't observed, and unable to understand what our experimental results are telling us. What theory do we need to know and/or develop in order to be able to move into a more productive and more scientific mode of research?

Targeted Poster Session: TP-B

Beyond Student Transfer: Graduate, Post-doc, and Faculty Development and the Road to Sustainable and Scalable Inclusion of PER

Thursday, August 5
8:15 – 9:45 & 3:45 – 5:15
California Suite

Noah Finkelstein (noah.finkelstein@colorado.edu), University of Colorado, Boulder
Melissa Dancy, University of North Carolina, Charlotte

Goal: Participants will begin to explore the broad question of why and how PER-informed practices are taken up (or not). The particular focus of this session is on the graduate, post-doc, and faculty preparation in physics education research and related reforms. In this session we address two interrelated and important themes: i) grad, post-doc and faculty development ii) the broader systemic frameworks that shape faculty practice.

Theme: While the question of transfer of student knowledge from one domain to another is compelling, many of these results (and curricula built on these results) remain compartmentalized because of another failure of transfer--- to faculty practices. This session, as described by the title, will examine some of the factors influencing the transfer of (or scaling and sustaining of) physics education research and physics education research influenced reforms. The common focus of each of these posters is on faculty or future faculty development, programs that foster such development, and challenges to the broad preparation of current and future faculty.

Individual Poster Abstracts

TP-B1 **Beyond the Individual Instructor: Systemic Constraints in the Implementation of Research-informed Practices**

Charles Henderson (Charles.Henderson@wmich.edu), Western Michigan University
Melissa Dancy, University of North Carolina, Charlotte

Anecdotal evidence suggests that findings of educational research and resulting curricula are, at best, only marginally incorporated into introductory physics courses. Many instructors do not appear to attempt changing from traditional, teacher-centered instruction to PER-informed instruction. Of those who do attempt such a change, many are unsuccessful. Based on interviews with a number of non-PER physics faculty we have considered why such a transition is uncommon. Elsewhere [1], we have reported on a preliminary analysis of this question from the standpoint of the individual instructor's beliefs and practices. But no instructor exists in isolation. They are embedded in the larger context of their department and institution, the educational system as a whole, and society. In this poster, we will report on a preliminary analysis of our interviews from this broader context rather than the individual instructor.

1. Dancy, M. & Henderson, C. Teaching, Learning and PER: Views from Mainstream Faculty, Summer 2004 AAPT meeting, Sacramento, CA.

TP-B2 **Encouraging Faculty to View Teaching and Learning as a Researchable Endeavor: A Transfer Perspective on the Role of Graduate Preparation**

Edward Price (edward@physics.ucsd.edu), University of California, San Diego

Refusal to consider education amenable to research methods remains a fundamental barrier to widespread acceptance of PER and research-based instructional practice. In this poster we consider this as a transfer problem: faculty possess expertise in systematically investigating physical phenomena through research, but do not transfer that investigatory approach and expertise to issues of teaching and learning. We analyze faculty views of teaching and learning in terms of factors known to impact transfer: the existence of a theoretical framework, context, representation of the problem, and culture. We focus on graduate education as an opportunity to facilitate this type of transfer by addressing these factors, discuss a graduate preparation program with this explicit goal, and evaluate the impacts on the participants and department.

TP-B3 Race, Culture and Transfer: Factors that Shape Faculty Attitudes and Beliefs about Race and Inclusion

Apriel Hodari (hodaria@cna.org), The CNA Corporation

Many faculty members realize that they need to find ways to connect to the diverse perspectives and experiences of all of their students. In the physics, it is often difficult to measure and address diversity issues because doing so is not perceived as central to our disciplines. In this poster, I examine the ideas of aversive racism [1] and colorblind racism [2], and how university faculty might address the challenges of inclusion in physics education reform and research. Results from a workshop designed to address these challenges, particularly by rejecting the "smog of bias" [3] will be presented.

1. Tatum, Beverly Daniel. (2004). Changing demographics and challenges of the future. Draft Proceedings of the National Science Board Workshop on Broadening the Participation in Science and Engineering Research and Education. Arlington, VA: National Science Board.
2. Bonilla-Silva, Eduardo. (2003). Racism without Racists: Color-blind Racism and the Persistence of Racial Inequality in the United States. Lanham, MD: Rowan & Littlefield.
3. Tatum, Beverly Daniel. (1997). Why are All the Black Kids Sitting Together in the Cafeteria? And Other Conversations about Race. New York: Basic Books.

TP-B4 Seeding Change: The Challenges of Transfer and Transformation of Educational Practice and Research in Physics

Noah Finkelstein (noah.finkelstein@colorado.edu), University of Colorado, Boulder

Academia appears to do a remarkable job at producing the next generation of research faculty. The long-anticipated shortage of well-qualified researchers has not appeared.[1] At the same time, while there are calls to reform educational practices in college and university classrooms, we are not widely preparing our future faculty to develop or implement these research-based educational practices. What mechanisms exist to foster the development of such practices and the field of PER more generally? What are the resources and impediments to do so? This poster examines the interrelated problems of supporting the development of the field, and the 'transfer' of what is known from PER to the more general populace of physics instructors. Two programs are examined to highlight these interrelated issues: the Postdoctoral Fellowships in Mathematics Science Engineering and Technology Education and the Preparing Future Physics Faculty Program. Data on successes and failures of these programs will be presented and analyzed from a perspective of cultural change [2] and developing professionals [3].

1. Committee on Science Engineering and Public Policy (COSEPUP). (2000). Enhancing the Postdoctoral Experience for Scientists and Engineers. Washington DC: National Academy Press.
2. Sarason, S.B. (1989). The Creation of Settings and the Future Societies. San Francisco: Jossey-Bass Publishers.
3. Shulman. L.S. (1997). Professing the Liberal Arts, In Education and Democracy: Re-imagining Liberal Learning in America, edited by Robert Orrill. New York: College Board Publications

TP-B5 Transfer From Graduate Experience to Faculty Practice: One Graduate Student's Experiences of and Ideas About Graduate Education in Physics

David Brookes (dbrookes@physics.rutgers.edu), Rutgers University

Viewed through the lenses of cognitive apprenticeship and legitimate peripheral participation, [1] graduate preparation in forms of education in physics departments is often a dismal failure. In searching for reasons for this failure, I will recount some of my own experiences and the experiences of my peers. I will then identify some factors that may be causing and may be sustaining the status quo. I will also discuss some ideas for both graduate students and faculty about how graduate education could be conducted differently and perhaps more effectively.

1. Lave, J., & Wenger, E. (1990). Situated Learning: Legitimate Peripheral Participation. Cambridge, UK: Cambridge University Press.

Targeted Poster Session: TP-C

Going Up? Learning Transfer Among Students in Upper-Level Physics Courses

Thursday, August 5
8:15 – 9:45 & 1:45 – 3:15
Lobby Suite

Chandralekha Singh (clsingh@pitt.edu), University of Pittsburgh
Bradley Ambrose (ambroseb@gvsu.edu), Grand Valley State University

Goal: It is well documented that introductory physics students find it difficult to take a physical concept covered in one context and apply it successfully to a different context. However, we expect that this kind of learning transfer would improve as one gains experience in physics. Thus a central research question we will explore and the complexity of which we hope the participants will appreciate is this: To what extent do students in upper-level physics courses demonstrate learning transfer? The presenters will discuss specific examples from their own research.

Theme: The theme of this targeted poster session is transfer of learning among students in upper-level physics courses. The theme is tied to the general theme of the conference. In this poster session the presenters define transfer of learning as the ability to apply a physical concept successfully to a situation different from that in which the concept was introduced [1]. For students in first-year physics courses, previous research has shown that learning transfer is usually very difficult. For students in a particular upper-level course, the question of learning transfer becomes more complex in that the requisite concepts may have been covered at the introductory level (e.g., Newton's laws, energy conservation) or at an earlier stage in that same upper-level course. The presenters will use examples from their own research, conducted in a variety of upper division courses (e.g., modern physics, intermediate mechanics and thermal physics), to discuss the extent to which the students in those courses demonstrate transfer of learning. Some presenters will also discuss preliminary work in developing instructional strategies designed to improve transfer of learning, by combining qualitative (conceptual) and quantitative problem solving or by giving students explicit guidance in applying a particular concept in different contexts.

1. Transfer of learning: Contemporary research and applications. S. M. Cormier and J. D. Hagman (eds.), New York: Academic Press, 1987.

Individual Poster Abstracts

TP-C1 Transfer of Learning in Quantum Mechanics

Chandralekha Singh (clsingh@pitt.edu), University of Pittsburgh

Although learning is highly context-dependent, the ability to transfer knowledge improves as one develops expertise in a particular domain [1]. Our preliminary studies show that transfer of learning is challenging even for advanced undergraduate students. In quantum mechanics, we want students to be able to transfer their learning related to wave phenomena, probability theory, and linear algebra from their previous courses. We also expect students to be able to apply the ideas learned in the same course in one context to a somewhat different context. We will discuss the extent to which transfer actually occurs in appropriate cases and explore cases where transferrance of classical or semi-classical ideas makes learning quantum physics even more challenging

1. M. L. Gick and K. J. Holyoak, *The cognitive basis of knowledge transfer*. In Cornier & Hagman (Eds.), *Transfer of learning: Contemporary research and applications*. New York, Academic Press, 1987.

TP-C2 A Repeat Performance? Challenges in Developing Robust Conceptual Understanding Among Advanced Students: Examples from Intermediate Mechanics and Modern Physics

Bradley Ambrose, (ambroseb@gvsu.edu), Grand Valley State University

Ongoing research at Grand Valley State University (GVSU) is being used to develop and test instructional materials, modeled after Tutorials in Introductory Physics, [1] for use in teaching intermediate mechanics [2] and modern physics. An important question that has arisen from this work, and on which this poster will focus, is: To what extent should we expect upper-level physics students to be able to apply concepts previously covered in class even those addressed through PER-based instruction at the advanced level to different situations? Extensive research already conducted at the introductory level has revealed that such transfer is extremely difficult for beginning students to do on their own. Preliminary results from the present investigation indicate that such transfer can be just as difficult in upper division courses. These results suggest that, in order for modifications in such courses to yield robust student understanding, specific conceptual and reasoning difficulties must be addressed explicitly and at multiple instances during instruction.

1. L.C. McDermott, P.S. Shaffer, and the Physics Education Group at the Univ. of Washington (Prentice Hall, 2002).
2. B.S. Ambrose, Investigating student understanding in intermediate mechanics: Identifying the need for a tutorial approach to instruction, Am. J. Phys. 72 (4), 453 459 (2004).

TP-C3 **Student Learning in Upper-Level Thermal Physics: Comparisons and Contrasts with Students in Introductory Courses**

David Meltzer (dem@iastate.edu), Iowa State University

We found that students in an upper-level thermal physics course were in general quicker than introductory students at grasping and applying fundamental concepts. However, even quite capable upper-level students would falter unexpectedly and unpredictably on various conceptual difficulties that are common among introductory students. The unpredictable and inconsistent nature of this effect demonstrated that instructors must always be prepared to detect and address such difficulties in upper-level courses. Upper-level students seemed, in general, more receptive to employing qualitative reasoning using multiple representations, and capable of using it more effectively than introductory students. In addition, upper-level students were better able to utilize guided-inquiry curricular materials in the sense of reasoning with greater depth and grasping more subtle issues. However, although the overall level of preparation and ability was higher in the upper-level course, the broad range of preparation represented among the students presented various practical challenges to implementing active-learning instructional strategies.

TP-C4 **Tracing Difficulties with Relativistically Invariant Mass to Difficulties with Vector Addition of Momentum in Newtonian Contexts**

Andrew Boudreaux (boudrea@physics.wwu.edu), Western Washington University

For effective transfer of knowledge, it is necessary to break the transfer of conceptual difficulties. In physics courses that include special relativity, students are expected to relate the invariant mass of a system to the energy and momentum of the individual particles that make it up. Many have difficulty doing so. Necessary ideas are that the energy and momentum of each particle form components of a four-vector, and that the four-vector of the system is the sum of the individual four-vectors. Results from written questions show that some students' difficulties stem from a failure to treat energy-momentum as a vector. Introductory students experience related difficulties in a purely non-relativistic context: many fail to take the vector nature of three-momentum into account when relating the momentum of a system to the momenta of its constituents. Results suggest that this difficulty is widespread and persistent, and is not necessarily resolved through the study of advanced topics.

Targeted Poster Session: TP-D

Issues in Studying Transfer of Problem Solving Skills

Thursday, August 5
1:45 – 3:15 & 3:45 – 5:15,
Orchard Room II & III

Kathleen A. Harper (harper.217@osu.edu), The Ohio State University
Thomas Foster (tfoster@siue.edu), Southern Illinois University -- Edwardsville
David P. Maloney (maloney@ipfw.edu), Indiana Univ. Purdue Univ. Fort Wayne

Goal: Participants will leave the session with a sense of the current status of research about transfer in the domain of problem solving, how this research can inform classroom practice, an idea of the issues that might be reported on in the near future, and a better understanding of how research in this area is conducted. We will expose participants to several aspects of transfer related to physics problem solving. Some of these aspects are currently being explored, while others need to be addressed in the near future. We will present both types, relate them to the current state of knowledge in this area, and describe ways in which these studies are or might be executed.

Theme: As one of the co-organizers put it, 'Transfer is the holy grail of problem solving.' It is such a huge part of determining the effectiveness of any instructional intervention, and in the area of problem solving, in particular, it's quite difficult to design an effective study. Getting some of these issues out in the open for discussion will be of value to problem solving researchers and 'consumers' alike.

Individual Poster Abstracts

TP-D1 **Quantifying 'Near' and 'Far' Transfer**

Leonardo Hsu (lhsu@tc.umn.edu), University of Minnesota

Researchers typically characterize instances of 'near' and 'far' transfer by the similarity of the contexts between which the transfer occurs (or does not occur). However, who decides whether or not two contexts are 'similar?' Is it possible to determine if a given pair of contexts is more similar than another pair? We explore the possibility of developing criteria for quantifying the nearness or farness of the transfer of problem-solving skills.

TP-D2 **Transfer Among Physics and Other Content Areas**

Eric Brewe (ebrewe@hpu.edu), Hawaii Pacific University

Physicists tend to think physics is the foundation of all science. Of course, this is true. However, it is not the only science and therefore it is interesting to consider the influence of physics on other sciences as well as other sciences on physics. In terms of problem solving, the issue of transfer between subjects is of particular import. This poster will summarize research into transfer between and among science courses and physics.

TP-D3 **Problem-solving Transfer Between Mathematics and Physics**

Thomas Foster (tfoster@siue.edu), Southern Illinois University -- Edwardsville
Charles Henderson (Charles.Henderson@wmich.edu), Western Michigan University

Mathematics is the language of physics and many mathematicians study physics phenomena. For professionals in physics and math, there are often instances of transfer between the two disciplines. Yet, every physics instructor knows that many students have great difficulty in using even basic mathematical skills in the context of solving a physics problem. What do we know about the nature of this transfer problem? Is it perhaps that our mathematics colleagues are poor teachers, or are there deeper roots? This poster will describe the current knowledge about the transfer of problem solving skills between mathematics and physics and identify questions that remain unanswered.

TP-D4 **Problem Solving Skills and Problem Types: What Transfers?**

David P. Maloney (maloney@ipfw.edu), Indiana Univ. Purdue Univ. Fort Wayne

One often stated goal of teaching problem solving is to help students develop problem solving skills, but what does this mean? Are there general problem solving skills that transfer? Considering that problems vary along a number of dimensions, what might it be reasonable to expect about how different skills transfer between different kinds of problems? This poster will provide an outline of these ideas/issues and try to identify some research questions that merit investigation.

TP-D5 **Alternative Problem Types: Do They Facilitate Transfer?**

Kathleen A. Harper (harper.217@osu.edu), The Ohio State University

A great deal of research effort has been devoted to developing alternative problem types (e.g. context-rich problems, jeopardy problems, experiment problems, and ranking tasks). Proponents of these problem formats claim that they assist students in becoming more expert in their problem solving. If this is indeed the case, there should 1) be observable characteristics of students who are routinely required to work such problems and 2) at least some of these characteristics should transfer to other types of problems. This poster will first describe some alternative problem formats and the instructional goals associated with them. Then it will explore how some of these behaviors might be quantitatively measured and how future studies might be designed to assess the transfer of such behavior.

Targeted Poster Session: TP-E

Determining Transfer of Learning with Longitudinal Studies Using Grade and Demographic Data on Individual Students

Thursday, August 5
1:45 – 3:15 & 3:45 – 5:15
Forest Suite

Wendell Potter (potter@physics.ucdavis.edu), UC Davis, Physics Education Group

Goal: Participants will see examples of research studies that make use of grade and demographic data on individual students that can easily be obtained, both for particular physics courses as well as data on performance in other courses. Although these kinds of data, as opposed to aggregated data, are available, studies using these data are not particularly common in PER. Participants will be able to explore with the presenters some of the research questions, particularly related to transfer of learning, that studies using these kinds of data can address, as well as more practical issues relating to obtaining these data.

Theme: Ultimately, we are all interested in student learning. There are a variety of ways to probe learning, but there is one universally used measure: grades. Although grades are more closely tied to student performance than to learning, they are a readily available source of useful data on student performance. The advantage of grades is that they are automatically kept and archived, as are demographic data on individual students. With the now complete computerization of registrars' records, these data can be easily obtained by researchers. Also, with a little more effort, data on individual student performance within particular physics courses is available. The availability of these kinds of data makes it possible to track individual student performance over time, rather than simply observing aggregate performance by looking at class averages.

Many research questions having to do with transfer of learning can be addressed using data that tracks individual student performance. These questions include those that relate to the effects of pre-requisite knowledge and understanding on subsequent performance in physics courses. These questions might relate to transferability of skills and abilities developed in introductory physics courses to performance in courses that students take following their introductory physics. Or, these questions might relate to transferability of skill and abilities developed in one part of a physics course to performance in other parts of the course.

This targeted poster session will show examples of how data that tracks individual student performance can be used to address the kinds of questions mentioned in the previous paragraph.

Individual Poster Abstracts

TP-E1 **Persistent Changes in Student Thinking Following a Reformed Physics Course**

Wendell Potter (potter@physics.ucdavis.edu), UC Davis, Physics Education Group
Mark McKinnon, UC Davis, Physics Education Group & *Gregory Potter*, University of the Pacific

We have continued to analyze the performance of >8000 biology majors in an upper-level physiology course at UC Davis as a function of graduation GPA, gender, ethnicity, kind of physics course previously taken, and grade in that physics course. We find that a student's grade in the physiology course is significantly influenced by the kind of physics course previously taken (reformed or traditional at UC Davis or traditional elsewhere) when other factors are controlled for. Our results show that students who take the reformed physics course, Physics 7, at UC Davis, have a statistically significant grade advantage in the subsequent physiology course. Variations in the grade advantage as a function of the differences in particular physics and physiology course offerings and analysis of the abilities and knowledge probed by course exams and performance on the FCI provide insights into how the thinking patterns of some students are changed after taking Physics 7.

TP-E2 **Student Performance in Math and Physics Following a Preparatory Physics Course**

Edward Adelson (adelson@mps.ohio-state.edu), The Ohio State University

Student success in physics courses following a preparatory course was originally tracked for nine years. The data showed that math course failures prevented many of these students from taking the next physics course within one or two quarters after the preparatory course. Data has now been obtained for students who have taken the preparatory course in recent years.

With additional data it is possible to compare results for different teachers and a larger number of students. The results are consistent with studies tracking student performance on the basis of math preparation.

TP-E3 **Relationship of Particular Physics Skills Acquisition to Pre and Post Performance Indicators**

Austin Calder (calder@physics.ucdavis.edu), UC Davis, Physics Education Group
Emily Ashbaugh, UC Davis, Physics Education Group

Utilizing an 8,000-student sample taken from Physics 7, our current research focuses on the trends in performance in specific areas and tasks in physics and other academic areas. This sample of students consists of mainly life-science majors and is approximately 70% female. We have all of the grades from quizzes and final questions over three quarters in Physics 7. In addition we have information on graduating GPA, number of UC units completed, grades from any UC course, gender, ethnicity, major, birth date, and SAT I scores. This longitudinal data gives us insights about which skills transfer to functional understanding in physics and which skills benefit from a good foundation of physics.

Workshop: W-A

Getting Articles into Journals

Thursday, August 5
8:15 – 9:45 & 1:45 – 3:15
Delta Suite

Robert Beichner (beichner@ncsu.edu), North Carolina State Univ.

Goal: Participants will learn how to be more successful in getting research articles published.

Theme: Research isn't really "science" until it has been peer-reviewed and published. This workshop will present ways to increase the publishability of articles. Attendees will examine different types of journals, learn how to meet their individual formatting standards, and gain insight into how reviews are conducted.

Activities: Participants will compare different journals to help them "fine-tune" their writing style, review citation formatting, learn how to manage article layout, etc. They will see how to create articles using RevTex, the preferred form for submission to APS journals and the American Journal of Physics. After a thorough review of the steps required for a detailed review, attendees will work in groups to review example articles. (If space becomes a concern, we may need to limit attendance to only one participant per research group.).

Workshop: W-B

The Physics Portal: Building a Self-Sustaining Internet-based Education Network

Thursday, August 5
8:15 – 9:45 & 1:45 – 3:15
Auburn Room

David Hestenes (hestenes@asu.edu), Arizona State University
Bernard Haisch, ManyOne Network
Joakim Lindblom, ManyOne Network

Goal: This workshop will introduce the PER community to a terrific new opportunity for web based physics education on the forthcoming "ManyOne Browser" (check it out at http://www.manyone.net). We propose that the PER community represent the AAPT as stewards of a Physics Portal on the new "ManyOne Network." This would put PER in charge of world-wide internet access to the best physics and physics education web sites.

Theme: ManyOne Network, which will be wholly owned by a non-profit foundation, is building a global alliance of institutions, organizations, educators and other experts whose goals are: (1) to make available a new web browser that uses rich media, 3-D navigation to interactively convey information and education-oriented content, usable even with a dial-up Internet connection, and which is open-source based to foster unlimited development; and (2) to catalyze a worldwide effort in which stewards (experts, organizations, universities) organize the best information on the Internet into a Digital Universe that will be free to all and will create a public-service oriented, advertising-free subset of the Web (a PBS of the Web) that will over time become the "Encyclopedia Galactica" envisioned by Carl Sagan and Isaac Asimov. The browser and access to all educational material will be free to the public in perpetuity. Operating revenues are generated not from advertising, but by offering Internet access and other services to paid subscribers. We propose an educational partnership in which, representing the AAPT, the PER community takes stewardship of the Physics Portal, providing original content and editorially selected links to the best physics websites. The AAPT may also at its discretion choose to offer ManyOne paid services to its members in return for a share in the monthly revenues.

Workshop: W-C

Laboratory Mathematics and Science for Cognitive Development -- Dealing with the Real Level of our Physics Students

Thursday, August 5
8:15 – 9:45 (Folsom Room) &
3:45 – 5:15 (Auburn Room)

Jerome Epstein (jepstein@duke.poly.edu),
Polytechnic University

Description: This is a hands-on session allowing participants to experience directly material from the beginning, middle, and end of a comprehensive integrated program in basic mathematics and science, designed specifically to promote formal level thinking, developed 20 years ago under NSF sponsorship. Diagnostic testing shows that far more students than is commonly known enter physics with cognition and basic quantitative skills far lower than most believe, and probably far too low to benefit sufficiently from even high quality Interactive Engagement physics programs. The program is designed to meet this need. It has been well tested and information on outcomes will be available. The program is designed to gradually produce higher level thinking and skill levels, taking students in two semesters from having no concept of fractions and decimals to doing numerical calculus, and Newtonian kinematics and dynamics without resort to memorized formulas. Gains in basic skills are high and success in succeeding courses is increased. The presenter will suggest a trial of this program, for those who test as needing it, preceding a good I-E physics program. The overall normalized gain can be compared with those who test similarly on basic skills, but go directly into physics without this program.

Workshop: W-D

Transferring PER Results from the Domain of the Researcher to the Domain of the Practitioner

Thursday, August 5
1:45 – 3:15 & 3:45 – 5:15
Folsom Room

Kenneth Heller (heller@physics.umn.edu),
University of Minnesota
Patricia Heller, University of Minnesota
Edit Yerushalmi, Weizmann Institute
Thomas Thaden-Koch, University of Minnesota

Goal: Our goal is for participants to become familiar with fundamental difficulties of physics faculty using PER-inspired curricular materials, and with the importance of conducting research focused on physics faculty to address these difficulties. A further goal is that participants become familiar with a technique for collecting data about faculty conceptions and a useful representation of that data. Finally, we hope that an initial look at some data from the domain of physics problem solving will start a discussion about the need for other research directions.

Theme: The workshop theme is transferring knowledge about teaching and learning from the domain of the researcher to that of the practitioner. This transfer is both necessary and difficult. Although PER groups have produced research-based curricula and instructional methodologies that are superior to traditional instruction, most physics faculty have not chosen to incorporate them into their teaching. It is clearly difficult to communicate PER results in a way that is useful for physics instructors. Clear explanation, data, and coherence with accepted theory are not sufficient. In the same way that an improved understanding of students has aided the development of instructional methods more useful to students, an improved understanding of physics instructors should aid the development of curricular materials more useful to instructors. Research is necessary to guide the curriculum developer (the "transfer agent"), who must translate the results of PER from the research domain into the practitioner's domain.

Activities: The primary activity will allow participants to experience the technique of interviewing instructors about artifacts (solutions to an introductory-level physics problem); participants will perform short, structured interviews with each other. A follow-on activity will allow participants to familiarize themselves with research results, in the form of concept maps that represent hypotheses about instructors' beliefs about the teaching and learning of problem solving; participants will try to map results of their interviews onto the concept maps. Participants will also discuss implications for the design and packaging of instructional materials and for future research directions.

Contributed Posters

Wednesday, August 4
8:00 – 10:00pm
Union Ballroom II

Posters will be set up between 6:00 – 8:00pm on Wednesday, August 4 and will remain up until the end of the conference.
Presenters are requested to put up their posters in the assigned spot as per the room layout at the end of this Program

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We categorized the Contributed Posters (CP) based on the abstracts. The following themes emerged:

- Assessment Issues (CP-AI)
- Difficulties & Misconceptions (CP-DM)
- General Interest (CP-GI)
- Instructional Practices (CP-IP)
- Modeling Student Thinking (CP-MT)
- Technology in Research & Teaching (CP-TR)

Several posters may lie in more than one category, however for the purposes of organizing this session, we chose what we believed to be the most appropriate category for each poster. Below we have listed the posters by category.

Posters in each category will be located contiguously. A room layout for the Contributed Poster Session indicating the location of each poster is at the end of this Program.

Assessment Issues (CP-AI)

CP-AI01 The Design and Validation of the Colorado Learning Attitudes about Science Survey

Wendy Adams (wendy.adams@colorado.edu), University of Colorado, Boulder
Katherine Perkins (katherine.perkins@ colorado.edu), Noah Finkelstein, Carl Wieman & Michael Dubson, University of Colorado, Boulder

The Colorado Learning Attitudes about Science Survey (CLASS) is a new instrument designed to measure various facets of student attitudes and beliefs about learning physics. This instrument extends the work done by the University of Maryland [1], University of California, Berkeley [3] and Arizona State University [2] by probing additional facets of student attitudes and beliefs. It has been written to be suitably worded for students in a variety of different courses. This poster introduces the CLASS, its design and validation studies which include analyzing results from over 2400 students, interviews and factor analyses. Methodology used to determine categories and how to analyze the robustness of categories for probing various facets of student learning are also described. We discuss a variety of applications here and in a companion poster.

1. E. F. Redish et al, Am J Phys. 66, 212-224 (1998).
2. Halloun et al, Science and Education 7:6, 553-577 (1998)
3. B. White et al, presented at the American Education Research Association., Montreal, 1999 (unpub).
4. Supported by NSF

CP-AI02 Evaluating and Using BEMA (Brief Electricity & Magnetism Assessment)

Lin Ding (lding@ncsu.edu), North Carolina State University, Robert Beichner, Ruth Chabay (rwchabay@unity.ncsu.edu) & Bruce Sherwood (basherwo@unity.ncsu.edu), North Carolina State University

BEMA is a comprehensive multiple-choice test designed to assess students' mastery of fundamental concepts in electricity and magnetism after taking the calculus-based introductory E&M course [1]. We will present results of statistical studies that show that BEMA has good reliability, an important measure for evaluating a test, and we will briefly explain the reasons for doing such studies. BEMA has been used in previous comparisons of traditional and reform courses [2]. We plan to use BEMA in further studies in Spring 2004.

*Supported in part by NSF grant DUE-0320608.

1. Qualitative Understanding and Retention. AAPT conference, Denver, Aug. 14, 1997. Contributed talk, Ruth Chabay and Bruce Sherwood.
2. Matter & Interactions II: Electric & Magnetic Interactions. Ruth Chabay & Bruce Sherwood, Wiley 2002, http://www4.ncsu.edu/~rwchabay/mi

CP-AI03 Understanding the MPEX 'Expert': A Comparison with Traditional Physics Faculty

Elizabeth Gire (egire@physics.ucsd.edu), University of California, San Diego
Edward Price (edprice@ucsd.edu) & Barbara Jones, University of California, San Diego

Student responses on the Maryland Physics Expectations Survey (MPEX) are typically compared to an expert response. This expert response is a concurrence of results from N=19 PER-informed college faculty asked to respond to the survey items with the answers "they would prefer their students to give".[1] We have surveyed the faculty at a research university (many of whom are indifferent or antagonistic toward PER) to determine if the responses of general physics faculty are concurrent and aligned with the PER-informed 'expert' response. N=16 physics faculty members at the University of California, San Diego (UCSD) were asked to fill out the MPEX in a the same manner as the MPEX expert group. This population of respondents represents a wider range of experience with PER than the calibration group; a majority have limited or no knowledge of results from the field. On nearly half the items, their responses did not converge with the MPEX expert response. While the average was closer to the average 'expert' response than reported results on students*, the range of individual faculty member's responses was large. We consider the implications of this result on measuring faculty pedagogical sophistication and understanding changes in student MPEX responses following instruction.

1. Redish, et al., Am. J. Phys. 66, 212-224 (1998).

CP-AI04 A Conceptual Hierarchy of Lunar Phases?

Aaron Hines (ahines@siue.edu), Southern Illinois University - Edwardsville
Rebecca Lindell (rlindel@siue.edu), Southern Illinois University - Edwardsville

According to cognitive theory, to encourage the development of a scientific understanding, instructors need to be able determine if their students have a mental model of phenomena, how deeply rooted these mental models are, as well as how structured they are. The majority of research to date has focused on the discovery of the different mental models of specific phenomena, as well as how deeply rooted these mental models are. In this research project we utilized data obtained from the national field test of the Lunar Phases Concept Inventory (LPCI) to investigate the conceptual hierarchy across the eight different concept dimensions investigated by the LPCI by employing the psychometric theory of item response. Item response theory (IRT) looks for patterns of item response based upon underlying latent traits typically total score. Rather than use the typical total score to estimate the latent trait, this research utilized the understanding of the different dimensions of lunar phases as the latent trait. Preliminary results of this research will be reported.

CP-AI05 Eliciting and Representing Hybrid Mental Models

Zdeslav Hrepic (zhrepic@phys.ksu.edu), Kansas State University
Dean Zollman (dzollman@phys.ksu.edu) & N. Sanjay Rebello (srebello@phys.ksu.edu), Kansas State University

While constructing their understanding in various domains of physics, students go through transitional phases that may involve richly developed and consistently used mental models. These transitional models are unique cognitive structures composed of elements of both scientifically accepted and the most commonly used initial alternative models and have been previously referred to as hybrid models [1]. In this paper we discuss the main features of Linked Item Model Analysis (LIMA) - a novel method for eliciting and representing mental models in areas where hybrid models play a role in students' learning. We developed and applied the method in the domain of sound propagation. We also present the LIMA-based assessment package for eliciting students' mental models of sound propagation, consisting of tests in different contexts and associated spreadsheet-based software which are now available online for classroom use.

Supported in part by NSF Grant # 0087788.

1. Hrepic, Z., D. Zollman, and S. Rebello. Identifying students' models of sound propagation. in 2002 Physics Education Research Conference. 2002. Boise ID: PERC Publishing.

CP-AI06 Development of an Instrument for Evaluating Anxiety Caused by Cognitive Conflict*

Yeounsoo Kim (kim.1902@osu.edu), The Ohio State University
Lei Bao, The Ohio State University

Physics learning situations often involve many cognitive conflicts between a student's present understandings and new information being learned. Cognitive conflict is known as an important factor in conceptual change. Therefore, it is important to help physics teachers and students develop skills and knowledge for more effective conflict management. However there is no readily available method by which to identify the types of meaningful (constructive) cognitive conflict that students may have in their learning. We focus the study on the student anxiety caused by cognitive conflict so that we can improve student motivations in learning. This study is targeted to develop an easy-to-use instrument that can be implemented in classroom to monitor students' status of their anxiety in cognitive conflict situations and the effects on students' motivations in learning. We will show that this tool is useful for obtaining important information about the skills and procedures needed for effective conflict management in the physics laboratory like physics by inquiry.

This work was supported by Korea Research Foundation Grant. (KRF-2003-037- B00102)

CP-AI07 Using a Q-type Assessment Instrument to Study Correlation Between Teacher Attitudes and Student Perceptions of Physics Laboratories

Yuhfen Lin (yflin@mps.ohio-state.edu), The Ohio State University
Dedra Demaree (ddemar1@pacific.mps.ohio-state.edu)& Gordon Aubrecht (aubrecht.1@osu.edu), The Ohio State Univ., Xueli Zou (xzou@csuchico.edu), California State University – Chico

A modified version of the Laboratory Program Variables Inventory (LPVI),[1] a Q-type instrument originally developed to assess chemistry laboratories, has been used to study the correlation between instructor expectations and student descriptions. Careful study of the correlation among different classes shows that Q-type assessment is an effective tool for describing course types (as reported in a companion poster). Here we examine correlations between instructor expectations and student perceptions among different sections of the same course, as well as differences in student perceptions among the sections taught by the same instructor. This Q-type assessment tool may be used to diagnose problems in curriculum development and instructor education.

1. M. R. Abraham, 'A descriptive instrument for use in investigating science laboratories,' Journal of Research in Science Teaching 19 (2) 155-165 (1982).

CP-AI08 Measuring Conceptual Change in College Students' Understanding of Lunar Phases

Rebecca Lindell (rlindel@siue.edu), Southern Illinois University - Edwardsville

Researchers now know that college students enter the introductory astronomy classroom with pre-existing mental models of lunar phases. If rooted deeply enough alternate mental models may actually impair an individual's ability to learn a particular concept. To teach the subject successfully, instructors need to encourage conceptual change. To aid instructors in assessing individuals' mental models of lunar phases, the Lunar Phases Concept Inventory (LPCI) was developed. This twenty-item multiple-choice inventory was designed to advantage of the innovative model analysis theory. By using this theory in combination with the LPCI, an instructor can determine the probabilities of their class utilizing different mental models, as well as how consistently said mental models are utilized. To assess conceptual change, an instructor can use the LPCI to assess student's mental models both before and after instruction. As an example of this technique, analysis of pre- and post-test LPCI results will be reported.

CP-AI09 Student "Splits" Between Intuition and Scientist Answers*

Timothy McCaskey (mccaskey@physics.umd.edu), University of Maryland
Andrew Elby (elby@physics.umd.edu), University of Maryland

Previous work showed that, on FCI items, students indicate that the answer they "really believe" often differs from the answer they think a scientist would give [1]. However, interviews revealed that these "splits" could not be cleanly interpreted: sometimes they corresponded to a student's intuition, sometimes not [2]. For this reason, and because intuition splits are epistemologically interesting in their own right, we modified the FCI task. Students now indicate their 'scientist answer' and the answer that "makes the most intuitive sense" to them. New interviews established that the modified task suffers from fewer interpretive difficulties. In addition, evidence suggests that students reconcile concepts like Newton's laws with their intuition more effectively if such reconciliation is an explicit goal of instruction.

* Supported by NSF grant #REC-0087519.

1. T. McCaskey et al., 127th AAPT National Meeting (2003).
2. T. McCaskey et al., 128th AAPT National Meeting (2004).

CP-AI10 A Survey to Investigate Student Understanding of Quantum Tunneling

Jeffrey Morgan (jeffrey.morgan@umit.maine.edu), University of Maine
Michael Wittmann (michael.wittmann@umit.maine.edu), University of Maine

Initial interviews on quantum tunneling with undergraduate physics majors[1] have revealed that a significant percentage of students (a) believe energy is lost in tunneling and (b) have difficulty sketching and interpreting the wave function in the region of a potential barrier, corroborating the findings of Bao[2] and others[3]. We have used these results to construct a survey designed to probe student conceptual understanding of tunneling through a symmetric square barrier. The survey asks respondents to sketch the wave function in the region of a potential barrier, and to use their sketch to reason about both the probability of tunneling and the average energy of particles that have tunneled. Further questions involve changes to the barrier or the particle energy. We discuss the evolution of the survey design, as well as the responses of advanced undergraduate physics and engineering physics majors at the University of Maine during the 2002-03 and 2003-04 academic years.

[1], [2], [3] See Announcer Vol. 34, Summer 2004, pg. 172 for citations.

CP-AI11 Correlating Student Attitudes with Student Learning Using the Colorado Learning Attitudes about Science Survey

Katherine Perkins (Katherine.Perkins@colorado.edu), University of Colorado, Boulder
Wendy Adams (Wendy.Adams@colorado.edu), Steven Pollock, Carl Wieman & Noah Finkelstein, University of Colorado, Boulder

A number of instruments have been designed to probe the "hidden curriculum"[1], examining the variety of attitudes, beliefs, expectations, and epistemological frames taught in our introductory physics courses. Using a newly developed instrument – the CLASS[2] – we examine the relationship among students' attitudes and beliefs, their shifts over the course of a semester, and other educational outcomes, such as conceptual learning and student retention. We report results from surveys of 2400 students in a variety of courses, including several designed to promote favorable student attitudes. We find positive correlations between particular student attitudes and conceptual learning gains, and between student retention and favorable attitudes and beliefs in select categories. We also note the influence of teaching practices on student attitudes.

1. E. F. Redish, Teaching Physics with Physics Suite, Wiley 2003.
2. W. Adams et al., The design and validation of the Colorado Learning Attitudes about Science Survey, PERC 2004.

CP-AI12 Student Understanding of Gauss' Law of Electricity

Chandralekha Singh (clsingh@pitt.edu), University of Pittsburgh
Paul Reilly (clsingh@pitt.edu), University of Pittsburgh

We are investigating student difficulties and designing tutorials related to Gauss' law in introductory calculus-based courses. Our investigation includes interviews with individual students, development and administration of free-response pre-/post-tests, and development of a conceptual multiple-choice test. Results of our investigation will be discussed.

CP-AI13 From Students' Perspectives: A Q-type Assessment Instrument*

Xueli Zou (xzou@csuchico.edu), California State University - Chico
Dedra Demaree, Yuhfen Lin & Gordon Aubrecht, The Ohio State University

A Q-type instrument, the Laboratory Program Variables Inventory (LPVI)**, has been used to assess three possible different introductory physics laboratories: an investigative science learning laboratory at California State University, Chico (CSUC), Physics by Inquiry, and a regular calculus-based laboratory at The Ohio State University (OSU). The LPVI was originally developed to investigate three different laboratory formats—verification, guided inquiry, and open inquiry—used in college general chemistry courses. This poster will share LPVI's data and data analyses obtained from those physics laboratories. The results provide us with insight about how the students perceive each laboratory learning environment and with feedback on further development of current curricula.

*Supported in part by NSF DUE # 0242845 and #0088906.

**M. R. Abraham, "A descriptive instrument for use in investigating science laboratories," Journal of Research in Science Teaching 19 (2) 155-165

Difficulties & Misconceptions (CP-DM)

CP-DM01 Rate of Change and Electric Potential

Rhett Allain (rallain@selu.edu), North Carolina State University
Robert Beichner (beichner@ncsu.edu), North Carolina State University

This project aims to investigate a possible underlying cause to student difficulties relating change of electric potential to electric field. A likely source of difficulties is the lack of students' understanding of the general concept of rate of change (both rate of change in time and distance). To investigate this link, a diagnostic was created that probed students' understanding of rate of change concepts and electric potential concepts. This poster will report on the creation of the diagnostic instruments and results from student responses.

CP-DM02 Diminishing Forces – Implications of a Misconception

Alicia Allbaugh (allbaugh@rit.edu), Rochester Institute of Technology

Evidence is presented to suggest a misconception concerning motion of an object when acted upon by a force which decreases with distance. This evidence was collected during interviews of several above average calculus-based physics students. The students stated that the motion of an object would slow, even stop, if the force on decreased based upon its distance such as Coulomb's Law. This may not be surprising until viewed it in the light that many of these students didn't reveal this impetus or Aristotelian notion except with diminishing forces.

CP-DM03 Assessing Student Understanding of Wave Amplitude and Intensity

Lei Bao (lbao@pacific.mps.ohio-state.edu), The Ohio State University
Dedra Demaree (demaree.2@osu.edu), The Ohio State University

Students often confuse wave amplitude and intensity. They state that they see a wave peak at points of maximum interference. In order to better assess this confusion, a waves questionnaire was given to 259 students during the 3rd quarter introductory calculus-based physics class at the Ohio State University just after all lecture instruction regarding wave interference and diffraction had been completed. Although further study will be necessary to understand many of the student responses, several misconceptions were evident from the results. Among these are that a large number of students believe that interference is purely destructive interference; many think that the eye can distinguish wave peaks and troughs; and most students think the wave peaks are points of highest intensity. The detailed findings from the questionnaire will be reported in this poster.

CP-DM04 Student Difficulties with Graphical Representation of Vector Products: Crossing and Dotting Beyond t's and i's*

Warren Christensen (wmchris@iastate.edu), Iowa State University
Ngoc-Loan Nguyen (nguyenn@iastate.edu) & David Meltzer (dem@iastate.edu), Iowa State University

Recent research [1-3] has shown that students in introductory physics courses (both algebra- and calculus-based) have significant difficulty with the graphical representation of vectors. In order to understand concepts such as work, torque, and magnetic force on a charged particle, students must have a coherent understanding of scalar products and vector products. In the last two academic semesters we have been probing students' understanding by the use of a six-question multiple-choice quiz. Early results indicate that 1/3 of students fail to recognize the fact that the scalar product of perpendicular vectors is zero. Another third of students fail to assign negative values to scalar products of two vectors with a vertex angle greater than 90 degrees. Another intriguing aspect of this poster will be to highlight some significant findings concerning the self-selecting nature of a student sample when using an online medium.

*Supported in part by NSF REC #0206683

1. R.D. Knight, Phys. Teach. 33, 74 (1995)

2. L.G. Ortiz, P.R.L. Heron, P.S. Shaffer, and L.C. McDermott, AAPT Announcer 31(4), 103 (2001)
3. N-L Nguyen and D.E. Meltzer, Am. J. Phys. 71, 630 (2003)

CP-DM05 Identifying Student Concepts of "Gravity"

Roger E. Feeley (roger.feeley@umit.maine.edu), University of Maine
John R. Thompson & Michael C. Wittmann, University of Maine

We have investigated student concepts of "gravity" among non-science majors, pre-service K-12 teachers, and high school students. Both interview and survey questions were developed or modified from those in the literature [1, 2, 3]. Students were questioned on their reasoning about the behavior of objects on the surface of a planetary body (e.g., the Earth or the moon) and the causes of this behavior. Results will be presented indicating that the survey successfully elicited student difficulties with various aspects of gravity, including the tendency to attribute gravity to the presence of an atmosphere, and to dissociate the concepts of gravity and weight.

[1], [2], and [3] See Announcer Vol. 34 p117 for citations.

CP-DM06 Student Understanding of Gravitational Potential Energy and Moving Objects

Michael Loverude (mloverude@fullerton.edu), California State University - Fullerton

We have been investigating student understanding of energy concepts in the context of introductory courses for non-science majors as well as those for science and engineering majors. We have found that many students develop incomplete understandings of the concept of gravitational potential energy. Moreover, students often make incorrect notions about the motion of bodies under the influence of gravity. These incorrect beliefs may prevent the development of a coherent understanding of energy as a conserved quantity. Examples will be presented of student responses to written questions and those posed in interviews.

CP-DM07 Student Understanding of Sound Propagation: Research and Curriculum Development

Katherine Menchen (Katherine.menchen@umit.maine.edu), University of Maine
John Thompson (John.Thompson@umit.maine.edu), University of Maine

Our ongoing research involves exploring student understanding of sound and sound phenomena as part of the process of developing instructional materials to improve student learning, especially among preservice teachers. Our current focus is on sound propagation. We have previously reported, based on responses to written questions, that the concepts of propagation and resonance are not functionally distinguished by many students.[1] More recent student interview data confirm this earlier work. In addition, the interviews indicate student difficulties with certain properties of media or objects that are propagating sound. We have been using our research results to develop curriculum that addresses the difficulties described above. For example, establishing clear boundaries that distinguish between situations involving propagation and those involving resonance is an important step in resolving these issues. We will discuss our findings, as well as how they have shaped the curriculum.

1. K.VP. Menchen and J.R.Thompson, "Preservice teacher understanding of propagation and resonance in sound phenomena," accepted for publication in 2003 PERC Proceedings

CP-DM08 Contrasts in Student Understanding of Simple E&M Questions in Two Countries

Cristian Raduta (raduta@rocketmail.com)
Gordon Aubrecht (aubrecht@mps.ohio-state.edu), The Ohio State University

We administered a survey on electricity and magnetism to two populations of students: one from Ohio State University, the other from Bucharest University (Romania). The survey had two questions, each composed of multiple parts. One question invited use of Gauss's Law in several different circumstances. Students answers to the Gauss's Law question were disappointing. A bare majority could solve the simplest problem, that of the field inside a conductor. The other question asked about the force and trajectory of charged particles in regions of magnetic field. These questions rely on understanding the Lorentz force and on transfer of general knowledge from classical mechanics studied earlier. Mechanics knowledge learned earlier apparently does not transfer to E&M. Transfer of learning about electricity and magnetism in both countries apparently is less successful than we, as teachers, would have wished.

General Interest (CP-GI)

CP-GI01 Design-Based Research: A Primer for Physics-Education Researchers*

Richard Hake (rrhake@earthlink.net), Indiana University

Some prominent education researchers now work in Pasteur's interdisciplinary, use-inspired, basic-research quadrant doing what they call 'Design-Based Research' (DBR). After quoting descriptions of DBR by a few of its advocates, I discuss the insularity that has hidden DBR's from PER's and PER's from DBR's. I then attempt to make the case that: (a) some PER is also DBR; (b) randomized control trials (RCT's) - not generally a part of DBR - are not the 'gold standard' of educational research, as hailed by the U.S. Dept. of Education; (c) DBR might develop into a force sufficient to accelerate even the ponderous educational system: (d) the pre/post test movement, generally ignored by the education community, could be a major component of that reforming force; and (e) non-classical analyses of tests heretofore used primarily for pre/post testing might assist the understanding of 'transfer.'

Submitted to the AJP on 6/10/04; online as ref. 34 at <http://www.physics.indiana.edu/~hake>.

CP-GI02 Are Physics Graduate Students' Beliefs About Teaching and Learning Consonant?

Yuhfen Lin (yflin@mps.ohio-state.edu), The Ohio State University

Gordon Aubrecht (aubrecht.1@osu.edu), The Ohio State University

Most physics graduate students teach as recitation or lab instructors in introductory physics courses at the same time they take graduate level courses. These students may or may not apply the same standards they expect in the courses they take to their own classes. We investigate whether they apply similar or distinct standards to these courses. This talk focuses on aspects of both teaching of and learning by OSU Physics Department graduate students as they have self-reported in a survey. What do they think teachers should do to help their students learn? What is their plan for their own teaching so that they could accomplish that goal? What is their expectation from their graduate study? What do they hope to gain from their graduate level courses?

CP-GI03 The Journal of Research in Science Teaching

Edward F. Redish (redish@umd.edu), University of Maryland

J. Randy McGinnis (jm250@umail.umd.edu), University of Maryland & *Angelo Collins* (angelo.collins@kstf.org.), Knowles Science Teaching Foundation

As of January 2005, the Journal of Research in Science Teaching and Learning (JRST) will be under new editorship. The new editors would particularly like to invite the discipline-based education research community to submit articles for publication in JRST. Although the journal is read by both researchers and practitioners, the focus is on research progress rather than research-to-practice. Studies by the American Educational Research Journal and the Educational Researcher for the American Educational Research Association identified JRST as one of the top research journals in science education. Many types of scholarly manuscripts about research on science teaching and learning are within JRST's domain, including but not limited to: investigations, employing experimental, qualitative, ethnographic, historical, survey, philosophical, or case study research approaches; position papers; policy perspectives; and critical reviews of the literature. After January, all submissions and correspondence will be electronic, though the journal will continue to be published on paper.

Instructional Practices (CP-IP)

CP-IP01 Can Inquiry Experiences in Physics Class Change Students' Preconceptions About Teaching?

Gordont Aubrecht (aubrecht@mps.ohio-state.edu), The Ohio State University

In teaching inquiry classes in physics, we ask students to reflect on their learning in journals. One of the journal questions deals with student expectations of transfer of the inquiry techniques used in our class into their own classrooms when they become teachers themselves. We report on students' answers to this question over our decade-long experience in running inquiry courses, which gives insight into how much or how little the students think the techniques are worth to themselves as both students and prospective teachers.

CP-IP02 Use of a Hands-on Lab Exam to Investigate How Physics Students Transfer Knowledge from Lecture to the Laboratory

Duane Deardorff (duane.deardorff@unc.edu;duane.deardorff@unc.edu), University of North Carolina

For the past 4 years, an individual, hands-on lab exam has been administered to our introductory physics students. As advertised to the students in their lab manual, the purpose of this exam is to assess each student's ability to make accurate measurements with typical physics laboratory instruments, analyze and interpret empirical data, apply fundamental physics principles, design simple experiments, evaluate results, analyze measurement errors, and clearly communicate findings. These exams have generated a rich set of data that can be used to help answer a variety of research questions about how students make and analyze measurements. Selected findings from this investigation will focus on students' abilities and difficulties in transferring knowledge from the lecture to the laboratory setting.

CP-IP03 Virtual Reality Experiments in Introductory Physics Laboratories

Dedra Demaree (ddemar1@pacific.mps.ohio-state.edu), The Ohio State University
Stephen Stonebraker & Lei Bao, The Ohio State University

Physicists consider laboratories to be a vital part of any introductory course, yet students consistently rate them as having low value. The Ohio State University (OSU) Physics Department has modified the current introductory calculus based Physics laboratories to include Virtual Reality (VR) experiments developed by the PER group at OSU. These VR experiments, when implemented as a mix with traditional experiments, have the potential to improve upon many of the difficulties with traditional labs which cause student frustration. This poster explores some of the specific reasons that standard introductory physics laboratories are not having the expected impact, and describes how the implementation of Virtual Reality based experiments improves upon these issues. Student response to these experiments and preliminary results regarding their impact on student learning will also be discussed.

CP-IP04 Helping Preservice Teachers Implement and Assess Research-based Instruction in K-12 Classrooms

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Donna Messina (messina@ phys. washington. edu) & MacKenzie Stetzer (stetzer@phys. washington.edu), University of Washington

The Physics Education Group at the University of Washington offers special academic-year physics courses for preservice mathematics and physics teachers. The three-quarter sequence helps teachers develop an in-depth understanding of some of the important basic concepts they will be expected to teach. The guided-inquiry pedagogical approach provides an opportunity for teachers to learn as they will be expected to teach. As a result of the course, they also come to recognize some conceptual and reasoning difficulties commonly encountered by students. A culmination of their experience is a teaching practicum in which the prospective teachers apply what they have learned in middle or high school classrooms. Observations of the teachers as they design, teach, and assess their lessons contribute to our understanding of the type of preparation needed for them to be able to teach physics and physical science by inquiry.

CP-IP05 Can Computer Simulations Replace Real Equipment in Undergraduate Laboratories?

Noah Finkelstein (Noah.Finkelstein@colorado.edu), University of Colorado, Boulder
Katherine Perkins (Katherine.Perkins@ colorado.edu), Wendy Adams (Wendy.Adams@ colorado.edu) & Patrick Kohl (Patrick.Kohl@ colorado.edu), University of Colorado, Boulder

This poster examines the effects of substituting computer simulations in place of real laboratory equipment in the second semester of a large-scale introductory physics course. The direct current (DC) circuit laboratory was modified to compare the effects of using computer simulations with the effects of using real light bulbs, meters and wires. Three groups of students, those who used real equipment, those who used computer simulations, and those who had no lab experience, were compared in terms of their mastery of physics concepts and skills with real equipment. Note the complete author list: N. D. Finkelstein, K. K. Perkins, W. Adams, P. Kohl, and N. Podolefsky

CP-IP06 **Learning Physics by Listening to Children**

Danielle Harlow (Danielle.Harlow@colorado.edu), University of Colorado, Boulder
Valerie Otero (Valerie.Otero@colorado.edu), University of Colorado, Boulder

This study provides evidence to support the claim that prospective elementary teachers can deepen their understanding of physics through analysis of the 'physics talk' of elementary students. Elementary Student Ideas (ESI) activities, one component of the Physics for Elementary Teachers (PET) curriculum*, are homework and in-class assignments in which prospective and practicing elementary teachers watch and analyze video clips of elementary children talking and learning about physics topics. By observing perspective and practicing elementary teachers engaged in ESI activities, we have recognized that these adult students not only learn to listen to children; they also benefit from reflecting on their own learning of physics content in the context of listening to and analyzing elementary children's discourse about the same topics. In this study, we examine the role of ESI activities in the practicing and perspective teachers' learning of physics content.

This project is supported by the National Science Foundation Grant #0096856.

CP-IP07 **Evaluating Options for Combating Post-Exam Syndrome**

Kathleen Harper (harper.217@osu.edu), The Ohio State University
Matt Finnerty & Robert W. Brown, Case Western Reserve University

A previous talk described exam correction assignments to assist students in using midterms as a learning tool.1 Preliminary results suggested that student learning resulted. Some new studies strive to answer several subsequent questions: Does learning result from the nature of the assignment, or from the students simply putting in additional time with the material? Does working additional problems on a topic post-exam impact student learning of the material? Does the way in which instructors present and/or explain the exam-correction steps have an impact on learning? In the primary study, four parallel sections of a large course, after receiving back their graded exams, either did exam corrections, worked problems similar to the exam, or worked problems on new material. All took a follow-up test on the same topics as the initial test. The results from this study, and their implications for the issues described above, will be discussed.

1. K. A. Harper & R. W. Brown, "A Treatment for Post-Exam Syndrome," 128th AAPT National Meeting (2004).

CP-IP08 **Teaching, Learning and PER: Views from Mainstream Faculty**

Charles Henderson (Charles.Henderson@wmich.edu), Western Michigan University
Melissa Dancy (dancy@email.uncc.edu), University of North Carolina - Charlotte

Anecdotal evidence suggests that findings of educational research and resulting curricula are, at best, only marginally incorporated into introductory physics courses. We are working on a long-term project to provide the PER community with information that will facilitate the incorporation of research-based strategies and materials into mainstream physics instruction. In this talk, we will report on the pilot phase of this project which involved interviews with well respected and thoughtful senior faculty who are not part of the PER community. These interviews focus on their use of and attitudes towards PER and PER-based instructional strategies as well as their general beliefs about teaching and learning. Hypothesis will be made about some of the reasons why these instructors do not more fully incorporate PER into their instruction.

CP-IP09 **Electrostatic & Magnetism TIPERs***

Curtis Hieggelke (curth@jjc.edu), Joliet Junior College, Steve Kanim (skanim@nmsu.edu), New Mexico State University, David Maloney (maloney@ipfw.edu), Indiana University Purdue University - Fort Wayne, Thomas O'Kuma (tokuma@lee.edu), Lee College

This paper will illustrate materials from a collection of new instructional materials for the topics and concepts in electrostatics and magnetism. These materials can be used as classroom materials, quizzes or exam questions, or homework. These materials employ various TIPER (Tasks Inspired by Physics Education Research) formats that include: Ranking Tasks; Working Backwards Tasks; What, if anything, is Wrong Tasks; Qualitative Reasoning Tasks; Bar Chart Tasks; Conflicting Contentions Tasks; Linked Multiple Choice Tasks; Changing Representations Tasks; Meaningful, Meaningless Calculations Tasks; and other types of alternative task formats. The tasks are arranged into sets of issues that provide a way of asking similar or the same question in various ways. Such materials support active learning approaches, foster transfer of learning in the context of slightly different situations, and can be easily incorporated into current teaching formats without making major changes.

*Supported in part by CCLI grants # 9952735 and 0125831 from the Division of Undergraduate Education of the National Science Foundation

CP-IP10 Using The Schema Conceptual Tool To Promote Student Understanding Of Newton's 3rd Law

Brant Hinrichs (bhinrichs@drury.edu), Drury University

The Modeling Instruction program at Arizona State University has developed a conceptual tool, called a Schema, to help students make a first level of abstraction of a real physical situation. A schema consists of identifying and labeling all objects of interest from a given physical situation, as well as the different types of interactions between the objects. Given all the relevant objects and their interactions, students can explicitly identify which are part of their system and which are not, and then go on to model the interactions effecting their choice of system as either (i) mechanisms for energy transfer, or (ii) forces being exerted. In this poster, I describe the Schema tool, give examples of its use in the context of forces, and present some evidence on its effectiveness in helping student understand the 3rd law using the 3rd law questions from the FCI as my measure of effectiveness.

CP-IP11 Representational Format, Student Choice, and Problem Solving in Physics

Patrick Kohl (kohlp@ucsu.colorado.edu), University of Colorado, Boulder
Noah Finkelstein (noah.finkelstein@colorado.edu), University of Colorado, Boulder

Student problem-solving ability appears to be tied to the representational format of the problem (mathematical, pictorial, graphical, verbal). In a study of a 367-student algebra-based physics class, we examine student problem solving ability on quizzes involving four different representational formats, with problems as close to isomorphic as possible. In addition, we examine students' capacity for representational self-assessment by giving follow-up quizzes in which they can choose between various problem formats, and look for factors that may influence their ability or choices. As a control, part of the class was assigned a follow-up quiz with a random format, allowing a comparison with the group provided with a choice. We find that there are statistically significant performance differences between isomorphic problems. We also find that allowing students to choose which representational form they use increases student performance under some circumstances, and reduces it in others.

CP-IP12 In Class Polling: An Instant Feedback of Students' Learning Mode

Pengfei Li (Li.427@osu.edu), The Ohio State University
Neville Reay (reay@mps.ohio-state.edu) & Lei Bao (lbao@pacific.mps.ohio-state.edu), The Ohio State University

At The Ohio State University, Voting Machine (VM), an in-class polling system was used as an effective lecture instrument to teach students in an introductory electromagnetism class. A sequence of three questions (basic, intensive, extensive) was chosen as a useful tool to trigger the student into learning mode. In this talk, we will discuss the methods and the results of our numerical analysis and examples of student behavior patterns extracted from such analysis.

Supported in part by NSF grant # REC-0087788 and REC-0126070

CP-IP13 Attitudes of General Science Students Towards Learning Science and the Nature of Science

Jeff Marx (jmarx@mcdaniel.edu), Shabbir Mian (smain@mcdaniel.edu) & Vasilis Pagonis (vpagonis@mcdaniel.edu), McDaniel College

We investigated general science students' attitudes regarding the acquisition of scientific knowledge and the nature of science itself, by administering a 32-item survey combining and expanding on the Epistemological Beliefs Assessment for Physical Science (EBAPS) and the Maryland Physics Expectations Survey (MPEX). The survey authors (Laura Lising and Andy Elby, with Priscilla Laws and David Jackson) constructed their tool around five epistemological clusters – the organization of scientific knowledge, accruement of new knowledge, relationship between classroom science and the real world, evolution of scientific knowledge, and connections between assiduity and understanding [1]. To assemble a representative array of epistemological attitudes, we involved nearly 300 students from eighteen sections of three general science courses (A World of Light and Color; Astronomy; and Sound, Music and Hearing). We characterized the instructional styles for each course using three broad categories: traditional, transitional, and learning-centered. This poster will focus on the impact the different instructional styles had on students' epistemological belief clusters. In particular, we will highlight the effect of converting one of the courses (A World of Light and Color) from a transitional to learning-centered environment.

1. See http://www2.physics.umd.edu/~elby/EBAPS/home.htm and http://www.physics.umd.edu/rgroups/ripe/perg/expects/mpex.htm

Funded by the NSF and McDaniel College's Ira Zepp Teaching Enhancement Grant

CP-IP14 Gender Equity Variations in a Large Active-Learning Introductory Physics Course

Mark McKinnon (mlmckinnon@ucdavis.edu), University of California, Davis

At the University of California at Davis, the introductory physics course for life science majors has been employing an active-learning approach since 1996. Currently, more than 1400 students begin this course each year. One of the surprising developments has been the significant improvement in gender equity over the traditional physics sequence. We are now focusing more attention on utilizing student performance to quantitatively explore a broad range of issues related to active-learning approaches and the role that they play in gender equity. In class, small groups of five to six students team to complete activities designed to elicit discussion about physical concepts. As the activities were annually modified, opinions differ on the effectiveness of each variation. I used two variations of laboratory activities, one less formulaic than the other. I will present findings of the relative gender equity as measured by quiz performance of these variations.

CP-IP15 Transfer of Teaching: An Experiment of Opportunity

Robert A. Morse (robert_morse@cathedral.org)
H. Wells Wulsin (wulsin@post.harvard.edu), Harvard University

To what extent can an experienced teacher's interactive engagement physics curriculum, developed over many years, be taken over by a teacher with only a few year's experience? A sabbatical leave for the first author provided an opportunity to try the experiment. The first author gave course materials and daily plan book used for introductory physics and AP Physics C to the second author, along with some mentoring both in person and by email. The second author, with two years of teaching experience adapted and used the materials "on the fly." FCI scores and gains and personal statements from both teachers will be presented.

CP-IP16 Helping Students Learn to Design Experiments in a Large-enrollment Introductory Laboratory Course*

Sahana Murthy (sahana@physics.rutgers.edu), Eugenia Etkina (etkina@rci.rutgers.edu), Rutgers University

The Physics and Astronomy Education group at Rutgers University is working on helping students develop scientific abilities that are used by experts in the process of research. This poster, as a part of that project, focuses on the ability to design experiments. We devised carefully structured laboratory tasks where students have to design an experiment to test a hypothesis or to solve a practical problem. We implemented these tasks in a large-enrollment introductory physics laboratory class (450 students). To reliably assess the development of scientific abilities, we created and tested scoring rubrics. We will show detailed examples of our design tasks and scoring rubrics, and samples of student responses scored with the rubrics. We discuss the improvement in students' abilities over the period of one semester, and examine the relationship between the development of students' scientific abilities and their performance on exams in the physics course.

* Supported in part by NSF grant #DUE-0241078.

1. Etkina, E. (2004). 'Developing and Assessing scientific abilities in an introductory physics course', AAPT Announcer, Vol. 33 (4), p. 85 (2004).

CP-IP17 No Single Cause: Learning Gains, Student Attitudes, and the Impacts of Multiple Effective Reforms in a Large Lecture Course

Steven Pollock (Steven.Pollock@colorado.edu), University of Colorado, Boulder

We examine the effects of, and interplay among, several proven research-based reforms implemented in an introductory large enrollment (500+) calculus based physics course. These interventions included Peer Instruction with student response system in lecture[1], Tutorials[2] with trained undergraduate learning assistants in recitations, and personalized computer assignments[3]. We took extensive survey data throughout the semester along with validated pre/post content- and attitude-surveys, and long answer pre/post content questions designed to assess learning gains and near transfer, to investigate complementary effects of these multiple reforms, and to begin to understand which features are necessary and effective for high fidelity replication. Our median normalized gain was 0.67 on the FCI, 0.76 on the FMCE, yet we find we cannot uniquely associate these gains with any individual (isolated) course components. We see no decline in self-reported student attitudes, but do find that attitudes and attitude shifts both correlate positively with conceptual learning gains.

1. Peer Instruction, E. Mazur
2. Tutorials in Introductory Physics, McDermott and Shaffer
3. www.lon-capa.org and www.thinkwell.com
Work supported by Pew/Carnegie, NSF, and APS PhysTec

CP-IP18 Teacher and Curriculum Factors that Influence Middle School Students' Sense-Making Discussions of Force/Motion

Cody Sandifer (csandifer@towson.edu), Towson State University

This study investigated small-group discussions in an inquiry-based middle school science classroom. The purpose of the study was to determine the teacher and curriculum factors that provide support (or not) for students' sense-making discussions. To do this, two student groups were videotaped as they participated in force/motion activities. Analysis revealed that sense-making discussion was influenced by teacher adherence (or not) to the curriculum philosophy, activity content, teacher and curricular guidance for the continuing evolution of student ideas, and other teacher and curriculum factors.

CP-IP19 The Role of Evaluation Abilities in Student Learning & Performance

Aaron Warren (Aawarren@physics.Rutgers .edu), Rutgers University
Alan Van Heuvelen (Alanvan@physics. rutgers.edu), Rutgers University

This poster presents research which is part of a larger initiative by the Rutgers University PAER group to help students develop scientific thinking abilities. In particular, we focus on developing abilities which are necessary for students to critically evaluate information. Such information can include proposed problem solutions, conceptual statements, experiment designs, and experiment reports. To develop and assess evaluative strategies among students, we are creating and testing a wide range of activities. This poster presents some examples of these activities, outlines several types of evaluative strategies students can use, and examines some preliminary results regarding the role various evaluative strategies play in student learning and performance.

Supported in part by NSF grant #DUE-0336713 and #DUE-02410781

CP-IP20 Student Participation in Normative Behaviors in a Physics for Elementary Teachers (PET) Classroom*

Benjamin Williams (bwilliam@sciences.sdsu.edu), San Diego State University

The Physics for Elementary Teachers (PET) curriculum is designed to encourage normative classroom behaviors such as respect for every student's contribution, requiring evidence to support any claim made, and student responsibility for individual learning. The design of this curriculum is informed by research demonstrating that students actively construct individual understandings in a social context. Instructors play a pivotal role in the development of normative behaviors by both modeling desired behaviors and by explicitly discussing these behaviors with students. Analysis of video data taken in one PET classroom yields a timeline showing increasing active student participation in the desired normative behaviors. This poster outlines the results of this analysis.

*Supported by NSF Grant ESI-0138900

Modeling Student Thinking (CP-MT)

CP-MT01 Generated Analogies as Assertions of Categorization

Leslie Atkins (atkins@umd.edu), University of Maryland

One could consider the appropriate use of analogy to be the epitome of transfer; indeed, research in transfer frequently concerns whether or not an analogy is mapped onto the desired target (e.g., Gick and Holyoak, 1980). Understanding analogies that students draw, then, is an important part of understanding the idea behind transfer. The focus on analogy research in science education and cognitive science, however, has primarily concerned how students interpret (or fail to interpret) analogies with which they have been presented. Such a focus misses features of analogy that occur when students spontaneously draw analogies. The research presented in this poster concerns the generation of analogies by students in science classrooms and presents a framework for understanding them. In this framework, analogies are assertions of categorization and transfer may be better interpreted as an act of appropriate categorization.

CP-MT02 Active versus Passive Learning

Florin Bocaneala (jgoe@pacific.mps.ohio-state.edu), The Ohio State University
Lei Bao (lbao@pacific.mps.ohio-state.edu), The Ohio State University

Almost everybody agrees that the students who are actively involved in structuring their study environment, who investigate their study matter by selecting and formulating their own questions, perform better. Is this circumstantial correlation? What is the dynamics behind increased performance and active involvement in learning? In order to address this questions, the authors present herein a theoretical model that allows the comparison between the active and passive learning styles.

CP-MT03 Concerning Scientific Discourse about Heat

David Brookes (dtbrookes@yahoo.com)
George Horton, Alan Van Heuvelen & Eugenia Etkina, Rutgers University

We aim to examine communication in physics from a linguistic perspective and suggest a theoretical viewpoint which may enable us to explain and understand many physics students' alternative conceptions. We present evidence, in the context of the concept of heat, that physicists seem to speak and write about physical systems with a set of one or more systematic metaphors. These metaphors are well understood in their community. We argue that physics students appear to be prone to misinterpreting and overextending the same metaphors and that these misinterpretations exhibit themselves as students' alternative conceptions or misconceptions. A detailed analysis of physicists' discourse about heat will be used to present evidence of a possible connection between students' alternative conceptions and the possibility that they are misinterpreting the metaphorical language that they read and hear.

CP-MT04 Introductory College Students' Explanations of Friction and Related Phenomena at the Microscopic Level

Edgar Corpuz (eddy@phys.ksu.edu), Kansas State University
N. Sanjay Rebello (srebello@phys.ksu.edu), Kansas State University

Introductory college physics students' explanations of friction and lubrication were investigated by conducting semi-structured clinical interviews. Interview questions were constructed in a way that students were led to explain phenomena that they observed at the atomic level. Analysis of data showed that students were able to come up with their own explanations of what is happening at the atomic scale when surfaces come into contact, although these explanations are not necessarily scientifically correct. It was apparent that students tended to explain phenomena at the atomic level by using attributes of macroscopic objects (e.g. by visualizing atoms as balls students tended to associate attributes of real balls to that of atoms). Results of the study will serve as a basis to design teaching interviews to help students construct more scientifically correct microscopic models of friction and lubrication.

Supported in part by NSF Grant REC-0133621.

CP-MT05 Evidence of Transfer in Interview Data

Paula V. Engelhardt (engelhar@phys.ksu.edu), Kansas State University

Transfer is the ability to utilize what one has learned previously in new situations. This paper will explore evidence of transfer by one student during the course of a single interview. The transcript will be analyzed from two perspectives: the actor-oriented model of transfer developed by Joanne Lobato and the Kansas State University Physics Education Research Group's framework.

This project has been supported in part by NSF grant REC-0133621.

CP-MT06 Model What You Preach: Explicitly Articulated Interactions for Transfer of Concepts by Physics Graduate Teaching Assistants

Cathy Ezrailson (ezrailson@yahoo.com)

This study used both quantitative and qualitative methods to gain an understanding, gleaned from examining, on several measures, the effects of explicit graduate teaching assistant training on GTA beliefs about the nature of physics and physics problem solving. In the treatment group, also examined were students' 1) conceptual grasp of the basic principles of force and motion as they problem solved in cooperative groups during recitation, 2) attempts to become more expert-like in building solution models of complex problem scenarios and 3) the process of learning transfer, during interactions between GTA-student and student-to-student. Transfer of learning can occur explicitly, implicitly and accidentally. The challenge is to be able to assess the process and positive aspects when it occurs.

This study synthesized active engagement strategies based on definitive prior research, e.g.: Heller, Keith & Anderson, 1992; MacIsaac & Falconer, 2002; Minstrell, 2001; Hake, 1998, and many others.

CP-MT07 Transfer Between Paired Problems

Kara Gray (kgray@phys.ksu.edu), Kansas State University

N. Sanjay Rebello (srebello@phys.ksu.edu), Kansas State University

Student reasoning was originally thought to be fairly stable. It has now become clear that students' ideas are not nearly as stable as originally thought. The question now has become just how unstable are students' ideas and what things can influence these ideas. This paper will cover a small portion of a larger study designed to address this question. An interview over basic mechanics questions will be used to show how the questions themselves influence the student's answer to the questions. Based on this transcript and other data collected during the study, students' ideas appear to be influenced not only by their experiences and the context presented in the question, but also by the context of the question. This analysis was done based on a new model of transfer called the actor-oriented transfer model developed by Joanne Lobato. This new model will also be discussed in the paper.

Supported in part by NSF Grants REC-0087788 and REC-0133621.

CP-MT08 Transfer: The Advantage of Simple Symbols

Andrew Heckler (heckler@mps.ohio-state.edu), The Ohio State University

Jennifer Kaminski (kaminski.16@osu.edu), Vladimir Sloutsky (VSloutsky@hec.ohio-state.edu), The Ohio State University

One of the goals of successful learning is transfer, or the ability to apply acquired knowledge outside the learning situation. However, spontaneous transfer is notoriously difficult to achieve even for relatively simple knowledge. One important issue is whether it is better to learn concrete or abstract knowledge first. This research argues that transfer of learning across domains can be facilitated when knowledge is expressed in an abstract, generic form. In two experiments, undergraduate students learned two isomorphic domains, based on the same algebraic group. The 'math' domain was expressed in a more abstract, generic form, whereas the 'science' domain was expressed in a more concrete form. In both experiments, transfer from more abstract to more concrete was greater than the reverse. In addition, Experiment 2 indicated that the use of concrete symbols may hinder learning. This research supports the point of view that learning mathematics facilitates learning science. It argues that while there may be learning benefits in using concrete materials for instruction, the learning costs are substantial, thus suggesting the need for a radical rethinking of how mathematics and science is taught.

CP-MT09 Sample Exams and Transfer in Introductory Mechanics

Carol Koleci (ck@wpi.edu), Worcester Polytechnic Institute
Charles Chretien (cj@wpi.edu) & Warren Turner (wturner@wpi.edu), Worcester Polytechnic Institute

We report on a continuing study at Worcester Polytechnic Institute concerning the use of sample exams to promote transfer in introductory mechanics. Do sample exam problems have to be easier or more difficult than the actual exam questions in order for students to demonstrate improved conceptual understanding? Previous exam data has been reported at past AAPT meetings, including last year's Physics Education Research Conference. A review of these data, in addition to qualitative analysis of survey responses, will be provided.

CP-MT10 Alternative Conceptions, Memory & Mental Model in Physics Education

Gyoungho Lee (ghlee@snu.ac.kr), Seoul National University
Jiyeon Park, Yeonsoo Kim, Lei Bao, The Ohio State University

There are two somewhat independent research traditions, which converge to suggest a form of knowledge representation: alternative conceptions and mental model. However we have little literature that explains what they are different from each other and from memory. This study tried to describe theoretical issues with some thoughts about how cognitive science and science education approaches can be best synthesized in order to approach these questions.

This work was supported by Korea Research Foundation Grant (KRF-2003-042-B00165)

CP-MT11 Investigating Students' Knowledge of Particle Structure of Matter in Different Cultures

Lili Cui (lili@phys.ksu.edu), Kansas State University
Dean Zollman (dzollman@phys.ksu.edu) & N. Sanjay Rebello (srebello@phys.ksu.edu), Kansas State University

This study is in the early stages of an investigation of students' models of the structure of matter. Initially, we will compare results for students in three different countries. We will administer a questionnaire, developed by Silke Melkelskis-Seifert in Germany, which includes Likert scale and open-ended questions. This questionnaire focuses on understanding students' models of matter at the microscopic level, such as the existence of very small particles, particular/continuous structure of matter, three (solid, liquid and gaseous) states and their relationship, density of matter, etc. The survey will be administered in North America, Europe and East Asia. Follow-up interviews will help us understand the models underlying students' responses.

CP-MT12 Student Descriptions of Refraction and Optical Fibers

Fran Mateycik (mateyf@rpi.edu), Rensselaer Polytechnic Institute
DJ Wagner (wagnerdj@rpi.edu), Rensselaer Polytechnic Institute, JJ River, Sybillyn Jennings (jennis@sage.edu), Sage College

This paper reports our research into how students describe and think about optical fibers and the physical phenomena of refraction and total internal reflection (TIR) basic to their operation. The study was conducted as part of the improvement and expansion of web-based materials for an innovative Rensselaer introductory physics course [1] which examines the physics underlying information technology. As we developed the prototype module, we examined students' understanding of the phenomena of refraction, TIR, and optical fibers through the use of clinical interviews. As students discussed refraction and tried to explain how optical fibers work, several patterns emerged. Our analysis of these patterns drives our assessment of the effectiveness of the revised materials in addressing students' transfer of learning as well as the development of a multiple-choice diagnostic tool. This paper presents our categorizations of student responses and discusses how we are modifying our materials to address these findings.

Materials found at
http://www.rpi.edu/dept/phys/ScIT/

CP-MT13 Transfer of Learning from Trigonometry to Physics

Darryl Ozimek (djozimek@phys.ksu.edu), Kansas State University
N. Sanjay Rebello (srebello@phys.ksu.edu) & Paula V. Engelhardt (engelhar@phys.ksu.edu), Kansas State University

We investigated students' learning, retention, and transfer from a trigonometry course to an algebra–based physics course. A multiple–choice survey was administered as a pre–instruction and post–instruction assessment. The survey consisted of questions pairs, abstract (mathematics) and conceptual (physics) questions at three hierarchical levels of thinking. Three semi–structured interviews used graduated–prompting to determine the ease at which students transfer what they have learned from mathematics (abstract) questions to similar physics (contextual) questions. Results indicate that students' thinking of trigonometric concepts occurs at different levels. Concepts at lower levels are retained and transferred to a greater degree than higher level concepts. Transfer was assessed from the perspectives of both the traditional as well as the contemporary models of transfer. This study has implications for instruction of both trigonometry and physics as well as suggestions for improving transfer of learning from one area to another.

Supported in part by NSF Grant DUE–0206943.

CP-MT14 Analogical Scaffolding of Abstract Ideas in Physics

Noah Podolefsky (noah.podolefsky@colorado. edu), University of Colorado, Boulder
Wendy Adams (wendy.adams@colorado.edu) & Noah Finkelstein (noah.finkelstein@colorado. edu), University of Colorado, Boulder

Physicists commonly use analogies to ground their understanding of abstract physics concepts. Textbooks, for example, often use water waves as an analogy for sound waves. This poster explores the notion of using substance based1 analogies (analogies based on experience with material substances and objects) to scaffold student understanding of more abstract concepts in physics. We examine one way students use analogies in one grounded domain to build analogical models in another more abstract domain. In preliminary studies of the process of analogical scaffolding, students were interviewed while using the Physics Education Technology2 (PhET) computer simulations of sound and radio waves. Some students used the sound waves simulation followed by radio waves. Other students saw the simulations in the reverse order. Our model of analogical scaffolding along with data from interviews of students will be presented.

1. Reiner M,Slotta J,Chi M,Resnick L(2000).Naïve Physics Reasoning: A Commitment to Substance-Based Conceptions. Cognition and Instruction,18(1),1-34.

Supported by the Kavli Foundation and the NSF.

CP-MT15 Learning and Knowledge Transfer Between Physics Problems

David Pritchard (dpritch@mit.edu), Massachusetts Institute of Technology
Elsa-Sofia Morote, Massachusetts Institute of Technology & Rasil Warnakulasooriya, The Ohio State University

We compare two equally skilled groups who solve pairs of tutorial and related problems in introductory mechanics at MIT using the web-based tutor, myCyberTutor. The two groups solve the problems in reverse order with respect to each other. The group that solves the tutorials first experiences twice as large a reduction in difficulty per unit of time spent on the tutorial problem as the other group experiences on the tutorial due to solving the related problem first. The time for completion graphs provides confirmatory analysis-preparatory problems reduce the time necessary to solve the following problem. Further evidence is obtained by analyzing the use of hints between the two related problems. The group which solves a problem in a given problem-pair first requests more hints than the group which solves it second and benefits from these hints in answering the second problem in the pair. We conclude that learning and knowledge transfer is better facilitated through a tutorial-first approach than by a problem-first approach. We find evidence of schema acquisition and support the cognitive theory of feedback as a form of information that helps students in physics learning.

CP-MT16 Multiple Representations: A Quantitative Study on Students Use of Free-Body Diagrams in Large Lecture Classes.*

David Rosengrant (rosengra@physics.rutgers. edu), Rutgers University
Alan Van Heuvelen (alanvan@physics. rutgers.edu) & Eugenia Etkina (etkina@rci. rutgers.edu), Rutgers University

The Rutgers PAER group is working to help students develop various scientific abilities. One of the abilities is to create, understand and learn to use for a qualitative reasoning and problem solving different representations of physical processes such as pictorial representations, motion diagrams, free body diagrams, and energy bar charts. Physics education literature indicates that using multiple representations is beneficial for student understanding of physics ideas and for problem solving. This poster investigates three issues: a) are students who use free-body diagrams to solve traditional problems more successful then those who do not; b) do students who use free-body diagrams in mechanics continue to use them in other areas of physics; and c) are students consistent in using free body diagrams correctly in these different conceptual areas.

Supported in part by NSF grants DUE 0241078, DUE 0336713

CP-MT17 Student Learning of Quantum Mechanics

Homeyra Sadaghiani (hsada@mps.ohio-state.edu), The Ohio State University
Lei Bao (lbao@mps.ohio-state.edu), The Ohio State University

Quantum physics is an abstract topic that not only deals with the inaccessible venues and concepts of the microscopic world, but also requires a certain degree of mathematical skill. In this study, we aim to determine the most important skills and concepts that can enhance students' performance in a quantum mechanics class. We would like to know, for example, if a relationship exists between particular math skills and understanding of quantum mechanics. In this talk we will discuss the research findings with specific examples.

Supported in part by NSF grant # REC-0087788 and REC-0126070

CP-MT18 The Structure of Intermediate Mechanics Students' Physics and Mathematics Intuitions

Eleanor C Sayre (le@fructose.umephy. maine. edu), University of Maine
Michael C Wittmann (wittmann@umit.maine. edu), University of Maine

As part of ongoing research into cognitive processes and student thought, we investigate the structure of physics and mathematics intuitions in intermediate mechanics students. Students compared various damped and undamped harmonic motions using both differential equations and verbal descriptions of physical systems. We present evidence from a reformed sophomore-level mechanics class which contains both tutorial [1] and lecture components. Preliminary data suggest that mathematics and physics intuitions, even in intermediate students, are poorly linked and occasionally lead to conflicting predictions.

1. Bradley S. Ambrose, 'Investigating student understanding in intermediate mechanics: Identifying the need for a tutorial approach to instruction,' Am. J. Phys. 72 (4), 453-459 (2004).

CP-MT19 Students' Conceptions About Probability in a Double-slit Experiment for Electrons and Potential Well Problems

Pornrat Wattanakasiwich (muay@physics. orst.edu), Oregon State University
Kenneth Krane (kranek@physics.orst.edu), Oregon State University

Understanding probability is critical in making sense of quantum physics. A few studies have been done in the area of modern physics, which were involved with students' understanding of probability or even higher level concepts of QM. In order to study students' conception of probability, we have been investigating students' understanding as revealed in three contexts—mathematical/classical probability, a double-slit experiment for electrons, and potential well problems. We conducted a two-tier diagnostic test and two interviews with students who were taking a modern physics class. The results from a diagnostic test and both interviews were compared to determine what perspectives of probability concepts that students were able to transfer between these three different contexts.

CP-MT20 What Changes Occur During Conceptual Change?

Michael Wittmann (wittmann@umit.maine. edu), University of Maine

In their 1998 paper, diSessa & Sherin [1] answer the question 'what changes in conceptual change?' by introducing the idea of coordination classes. These consist of readout strategies for gathering information about a situation and causal nets of activated resources that generate thinking in a situation. Several types of conceptual change have been described in the literature (e.g., incremental, wholesale, cascade, dual construction [2]). All can be described using coordination classes. In this poster, I illustrate each form of conceptual change schematically and suggest other possibile forms of conceptual change that may play a role in student learning of physics.

1. diSessa, A. A., and Sherin, B. L. (1998). What changes in conceptual change. International Journal of Science Education, 20(10), 1155-1191.
2. Demastes, S., Good, R., Peebles, P. (1996). Patterns of conceptual change in evolution. Journal of Research in Science Teaching, 33(4), 407-431.

CP-MT21 Physics Teachers' Studying Students' Perceptions Required For Transfer

Edit Yerushalmi (ntedit@wisemail.weizmann. ac.il), Weizmann Institute
Bat Sheva Eylon (nteylon@wisemail.weizmann. ac.il) & Rachel Seggev (ntseggev@wisemail. weizmann.ac.il), Weizmann Institute

Transfer is a central goal for problem solving, though it spans from transferring procedures within a finite set of similar "end of chapter problems" to developing independent learning skills. Students' perceptions regarding knowledge and learning are an important factor in achieving transfer goals. Teachers that renew their instruction methods to achieve these goals have to become more attentive to such students' perceptions. We conducted a cooperative inquiry workshop to support teachers that renew their instruction to develop students' independent learning skills in physics problems solving. In this paper, we describe how teachers raise issues related to students' perceptions of knowledge and learning, as well as the development of a questionnaire examining these issues, designed by both the teachers and the researchers. We present findings from the analysis of the questionnaire and look at how the teachers' thinking was reformulated as a result of the process to influence their instruction.

CP-MT22 Dynamic Assessment Of Student Understanding: Reflections From A Plane Mirror

Karen Cummings (cummingsk2@southernct.edu), Southern Connecticut State University,
Edward Grillo, Southern Connecticut State University

In this paper we explore students' pre-instruction knowledge of conceptual and procedural pieces of knowledge that we believe are prerequisite to one's ability to generate correct light ray diagrams. We do so within the domain of image formation by a plane mirror. In addition, we follow students as they transition between various states of understanding using "dynamic assessment" techniques. That is, we probe student understanding as it develops- throughout instruction-rather than only pre- and post-instruction. The research population is students in an algebra-based, introductory physics course at a medium-sized, urban, public university.

Technology in Research & Teaching (CP-TR)

CP-TR01 A Web-based Tool for the Analysis of Concept Inventory Data

Joseph Beuckman (joe@beigerecords.com), Southern Illinois University - Edwardsville
Rebecca Lindell (rlindel@siue.edu), Southern Illinois University – Edwardsville & Scott Franklin (franklin@piggy.cis.rit.edu), Rochester Institute of Technology

Computing technology now makes possible previously impractical methods of analyzing student assessment data beyond the traditional 'total average score' approach. Our new, web-based tool will allow researchers in any location to upload their data and quickly download a complete analysis report. Analyses eventually included with this tool will be basic test statistics, Model Analysis Theory results, concept structure analysis, Traditional Item Analysis, Concentration Item Analysis, pre and post test comparison, including the calculations of gains, normalized change and effect size. The tool currently analyzes data from the Lunar Phases Concept Inventory (LPCI). It will be expanded to analyze data from other commonly utilized concept inventories in the PER community and, eventually, from user-designed and uploaded conceptual domains and inventories. In this poster, we will discuss the development of this analysis tool, as well as present our results to date. Instructors and researchers are encouraged to use the latest version of the analysis tool via our website.

CP-TR02 Feedback with Web-based Homework and PADs

Scott Bonham (scott.bonham@wku.edu), Western Kentucky University

The Physics Applets for Drawing (PADs) allow students to interactively make graphs and other physics diagrams on the Web and have them evaluated. PADs are able evaluate qualitative as well as quantitative drawings and to give customized feedback. These features greatly expand the range of exercises possible in a web-based homework system and make the latter more able to support research-based curricula. While feedback is important in ensuring proper transfer of learning, it is a challenge to provide enough feedback so that students do not become stuck and frustrated while at the same time not so much that it enables students to avoid thinking, particularly in an on-line environment. In this paper six different approaches to computer-based feedback are discussed along with how PADs could be used the different approaches. Participants are invited to discuss and make suggestions as to how PADs could be best used to support research-based curricula.

Sponsered by National Science Foundation under grant DUE-0231353.

CP-TR03 Computerized Interactive Problem-solving Coaches

Leon Hsu (lhsu@umn.edu), University of Minnesota
Ken Heller (heller@umphys.spa.umn.edu), University of Minnesota

Computers can play an important role in physics instruction by coaching students to develop good problem-solving skills. Building on previous research on the teaching of problem solving and on computer-student interactions, we are designing computer tutorials that provide students with guided practice in solving problems. We present a prototype of a tutorial along with students' reactions to it and discuss some preliminary results regarding the transfer of problem-solving skills from the computer tutorials to pencil-and-paper.

CP-TR04 Student Difficulties with Computer Modeling: Using Protocol Data to Revise Instruction

Matthew Kohlmyer (makohlmy@unity. ncsu. edu), North Carolina State University
Ruth Chabay (rwchabay@unity.ncsu.edu) & Bruce Sherwood (basherwo@unity.ncsu.edu), North Carolina State University

Computer modeling, an important skill in modern physics research, is emphasized by the Matter & Interactions (1) introductory physics curriculum. Students in this curriculum write computer programs that model a wide variety of physical systems using an iterative application of fundamental physics principles. In order for students to be able to do this successfully, instructors must know the difficulties students have in learning computer modeling. Based on results from a think-aloud protocol study in Spring 2003 at NC State, instructional materials were designed and implemented at the beginning of the Fall 2003 semester. A second think-aloud protocol was then conducted to search for qualitative differences and similarities in students' difficulties and reasoning processes while engaged in computer modeling. Results of this study and how they affect the future instructional revision cycle for Matter & Interactions will be presented.

1. Chabay, R. & Sherwood, B. Matter & Interactions, New York, John Wiley & Sons, 2002.

CP-TR05 Toward an Effective Use of Voting Machines in Physics Lectures

Neville Reay (reay@mps.ohio-state.edu), The Ohio State University
Lei Bao (lbao@mps.ohio-state.edu) & Pengfei Li (li.427@osu.edu), The Ohio State University, Rasil Warnakulasooriya (rasil@MIT.EDU), Massachusetts Institute of Technology

"Voting Machines" (VM) is a generic name for wireless-keypad in-class polling systems used by students to answer multiple-choice questions during lectures. Use of VM with carefully designed sequences of multiple-choice questions and instantaneous voting summaries improved classroom dynamics and rapidly guided students through a step-by-step process of assimilating concepts in the electricity and magnetism quarter of a year-long beginning physics course. Raw and analyzed results, class surveys and sample question sequences will be presented for two lecture sections, one in which students voted in groups and the other in which they voted as individuals.

CP-TR06 A Study of Student Use of an Online Message Board in an Introductory Physics Class

Wenjuan Song (ws88@msstate.edu), Mississippi State University
Taha Mzoughi (mzoughi@ra.msstate.edu) & Anastasia Elder (aelder@ra.msstate.edu), Mississippi State University

We investigated the use of an online message board by students in an Introductory Calculus-based physics course. The paper will describe the student population, the format of the course taught, the type of messages posted by the students and the message board used. The study includes correlational analysis between the number of the various kinds of messages posted by the students, and the student performance in homework, tests and overall course grade. Further data provides insight on student beliefs about the use of message board.

CP-TR07 Using Electronic Interviews to Explore Student Understanding

DJ Wagner (wagnerdj@rpi.edu), Rensselaer Polytechnic Institute
JJ Rivera, Fran Mateycik (mateyf@rpi.edu), Rensselaer Polytechnic Institute, Sybillyn Jennings (jennis@sage.edu), Sage College

This paper reports on methods used to probe student understandings of optical fibers and total internal reflection (TIR). The study was conducted as part of the expansion and improvement of web-based materials for an innovative introductory physics course. Development of these materials includes the refining of multiple-choice diagnostic questions by examining preconceptions and misconceptions commonly held by students. Initially, we conducted face-to-face Piaget-style interviews with a convenience sample. Our next step was to interview students taking the course at Rensselaer. Physical limitations necessitated that this be done from a distance, so we conducted "e-interviews" using a Chat Room. In this paper we focus on the e-interview experience, discussing similarities to and differences from the traditional face-to-face approach. In the process, we address how each method informs us about students' activation of prior experiences in making sense of unfamiliar phenomena (e.g., "transfer of learning").

CP-TR08 Time for Completion Curves for Physics Problems

Rasil Warnakulasooriya (rasil@mit.edu), Massachusetts Institute of Technology
David Pritchard, Massachusetts Institute of Technology

Using myCyberTutor, a web-based homework tutor, we study how long it takes students to complete a given physics problem completely and correctly. We identify three major groups of students in completing a given problem. The students who were able to solve the problem quickly (< 2.5 min), we hypothesize are able to solve it through some insight or having worked it out previously. The major group of students who completes the problem (in 2.5 min to 2 hours) often uses hints and feedback. The third group takes over several hours, generally days. We hypothesize that they obtain help outside myCyberTutor. The middle part of the graphs (typically 2 min to 2 hours) of the fraction of students completing a given problem as a function of logarithmic time yields sigmoid curves as is often seen in the psychology literature. The sigmoid shape occurs only for problems containing hints. The shape for end-of-chapter problems that do not contain any hints tends to be linear with more students falling into the first (quick) and third (late) regions. Generally only about 45% of the students finish within 2 min to 2 hours. Certain best-fit functions (within 2 min to 2 hours) seem to be a feature of the problem regardless of whether that problem is done before or after a related problem. The group that does a problem second having solved a related problem first has an advantage in time over the group that solves the same problem first in most related problem-pairs. This difference is seen as measured by the shift in peaks of the gradient curves. The advantage (reduction) in median time to solution is as high as 35% with an average of about 12%. This shows evidence of learning from the first problem.

Roundtable Discussions

Wednesday, August 4
9:00 – 10:00pm
Lobby Suite

RT-01 **Students Making Sense for Themselves—A Different Paradigm in the Classroom**

Dewey Dykstra (ddykstra@boisestate.edu), Boise State University

What if instead of teaching physics content we engaged students in making sense of the phenomena for themselves? The existing paradigm seems to hold that students cannot know unless we "tell" them and that only a few students are really capable of knowing physics. It aims to some how transmit or inculcate the students with an official canon. What if we abandon that aim? What might be the outcome? There is evidence that some very good things would be the outcome. This roundtable discussion is intended to discuss a possible project to explore the pursuit of a different paradigm for classrooms from which students come having developed more powerful understandings of the phenomena, the skills at developing such understandings and the recognition that they can do so. Would such students show evidence of the capacity to transfer what they have worked out for themselves to new settings?

RT-02 **Student Understanding in Upper-Division Physics**

Ingrid Novodvorsky (novod@email.arizona.edu), Dept. of Physics, Univ. of Arizona

At the University of Arizona, we are beginning a long-term research project designed to determine how undergraduate physics majors conceptualize physics content as they progress through a degree program. We hypothesize that the success of this conceptualization is based on students' ability to transfer their learning from introductory courses to upper-division courses, in which they are expected to combine sophisticated mathematical techniques with underlying conceptual understanding. While the stronger students may be able to accomplish this combination, that skill is not automatic for all students, as many struggle just to keep up with the mathematical techniques, and others do not have a solid conceptual understanding of the underlying physics. We are in the early stages of conducting this research and invite other researchers to this roundtable to join the discussion and provide constructive commentary.

Instructions for Presenters

Contributed Poster Presenter Instructions

Preparation:

- Your poster must occupy an area **no larger than 4 feet x 4 feet**.
- We **will provide** you with **poster boards and thumb tacks**.
- There will be **no table** available for you to place any computer or demonstration equipment at the poster.
- There will be **no electrical power** source near your poster. So, if you need to use your laptop, please make sure it is fully charged before the session.

Putting Up:

- Please put up your poster between 6:00-8:00pm on Wednesday, August 4 in Union Ballroom-II.
- We have grouped the posters into what we believe are appropriate categories as per the information provided in the title and abstract. Please determine from the printed program (or by doing a search on this website) as to what category and code your poster has been assigned. Each poster has been assigned a spot so that all posters in the same category are contiguously arranged.
- Please **put up your poster in your assigned spot alone**. *Even if you believe that your poster was incorrectly assigned to a category, we would appreciate if you could kindly put it up in the assigned spot.*
- ***Post-deadline Poster Presenters***: We strongly discourage post-deadline submissions. However, if you are a post-deadline submitter we have spots marked with an **X** in the room layout. Please choose one of the spots marked with an **X** on the layout closest to a category that you believe your poster most closely lies.
- Typically you are sharing your 8 feet wide x 4 feet high poster board with another presenter. If you arrive to put up your poster first, please be sure to leave room for the poster that shares the board with you.

Exhibiting:

- Please ensure that either you or one of your co-authors is at your poster as follows:

  - If your poster is **odd numbered** (e.g. CP-MT**21**), then please be at your poster for the **first hour** i.e. from **8:00-9:00PM**.
  - If your poster is **even numbered** (e.g. CP-AI**08**), then please be at your poster for the **second hour** i.e. from **9:00-10:00PM.**

- In addition the Contributed Poster Session, we hope that the posters will be available for viewing all of Thursday, August 5 especially during the breaks. We strongly urge you to keep your poster up until you leave the conference.

Targeted Poster Presenter Instructions

Preparation:

- Each poster must occupy an area **no larger than 8 feet wide x 4 feet high**.
- You will be provided with as many poster boards as there are posters in your session, so that each poster can have one full poster board.
- You will be provided with thumb tacks and an overhead projector, but **no** computer projector.

Putting Up:

- Each Targeted Poster Session has a dedicated room. Although your session will meet twice during the day, you do not need to take down your poster until your second session meeting.
- We strongly urge you to put up your poster on Wednesday night, or early Thursday morning.
- You will be provided with as many poster boards as there are posters in your session. You may move these around as you wish into an arrangement that you most prefer. A suggested arrangement is to have the poster boards arranged around the room, with one side (that is not used) of each board against the wall, and the other side facing the audience.

Presentation:

In presenting your session, please keep the following guidelines in mind

1. The first 20-25 minutes for the discussant (organizer) to present the overarching theme and for the individual poster presenters to briefly describe their research that speaks to this theme.
2. For the next 40-45 minutes, participants walk around the room and interact with individual poster presenters. Please urge the participants to take the opportunity to circulate around the room and view all of the posters.
3. The last 20 minutes will be a panel discussion led by the discussant.

Workshop Presenter Instructions

- Please prepare materials for about 50-60 participants for each of your two sessions.
- You will be provided with a computer projector and any other special equipment or services that you requested (e.g. flip chart, tables, wireless internet etc.)
- Please inspect the room by Wednesday, August 4 and make sure that it meets all of your requirements.

PERC2004 Presenter List

Name – Last, First	Presentation Number
Adams, Wendy	CP-AI01, CP-AI11, CP-IP05, CP-MT14
Adelson, Edward	TP-E2
Allain, Rhett	CP-DM01
Allbaugh, Alicia	CP-DM02
Ambrose, Bradley	TP-C, TP-C2
Ashbaugh, Emily	TP-E3
Atkins, Leslie	CP-MT01
Aubrecht, Gordon	CP-AI07, CP-AI13, CP-DM08, CP-GI02, CP-IP01
Bao, Lei	CP-AI06, CP-DM03, CP-IP03, CP-IP12, CP-MT02, CP-MT10, CP-MT17, CP-TR05
Beichner, Robert	CP-AI02, CP-DM01, W-A
Beuckman, Joseph	CP-TR01
Bocaneala, Florin	CP-MT02
Bonham, Scott	CP-TR02
Boudreaux, Andrew	TP-C4
Brewe, Eric	TP-D2
Brookes, David	CP-MT03, TP-B5
Brown, Robert W.	CP-IP07
Calder, Austin	TP-E3
Chabay, Ruth	CP-AI02, CP-TR04
Chretien, Charles	CP-MT09
Christensen, Warren	CP-DM04
Collins, Angelo	CP-GI03
Corpuz, Edgar	CP-MT04
Cui, Lil	CP-MT11
Cummings, Karen	Invited Talk, CP-MT22
Dancy, Melissa	CP-IP08, TP-B, TP-B1
Deardorff, Duane	CP-IP02
Demaree, Dedra	CP-AI07, CP-DM03, CP-IP03, CP-AI13
DeWater, Lezlie S.	CP-IP04
Ding, Lin	CP-AI02
diSessa, Andrea	Invited Talk
Dubson, Michael	CP-AI01
Dykstra, Dewey	RT-01
Dziembowski, Zbigniew	Invited Talk
Elby, Andrew	CP-AI09
Elder, Anastasia	CP-TR06
Engelhardt, Paula V.	CP-MT05, CP-MT13

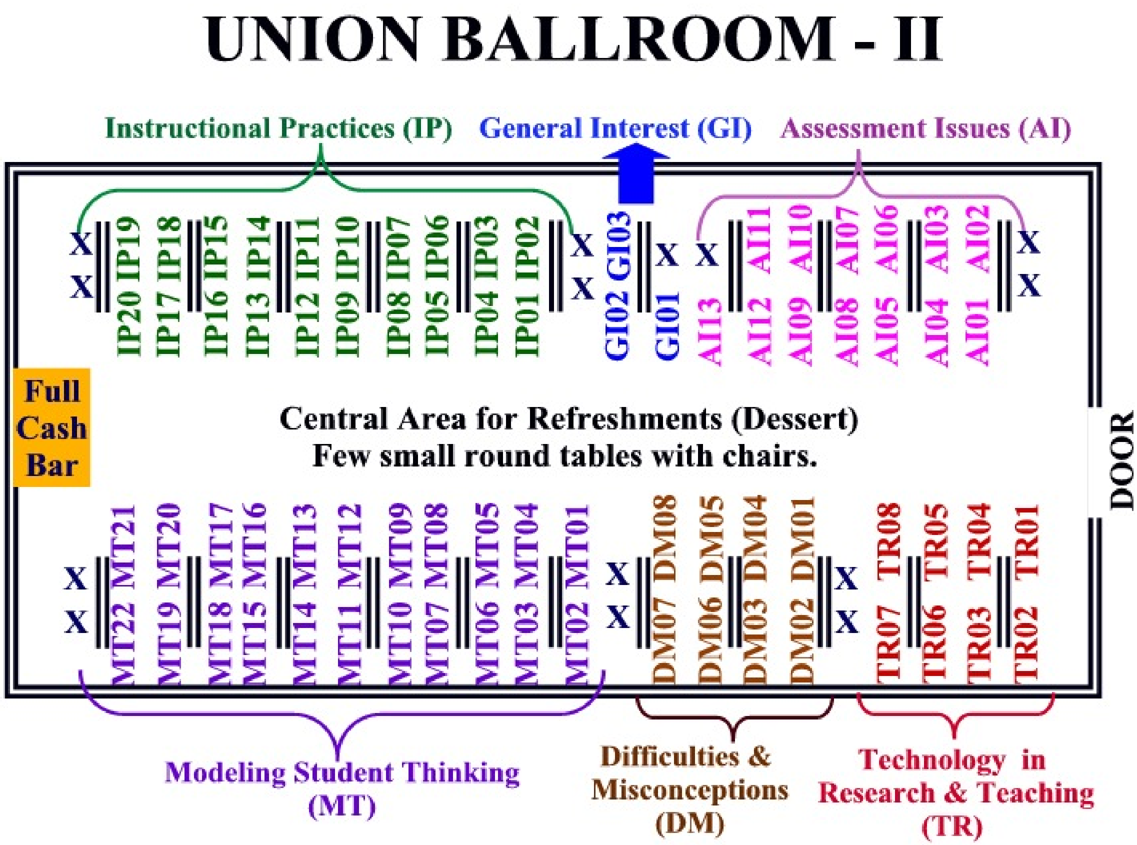
Name – Last, First	Presentation Number
Epstein, Jerome	W-C
Etkina, Eugenia	CP-IP16, CP-MT03, CP-MT16
Eylon, Bat Sheva	CP-MT21
Ezrailson, Cathy	CP-MT06
Feeley, Roger E.	CP-DM05
Finkelstein, Noah	CP-AI01, CP-AI11, CP-IP05, CP-IP11, CP-MT14, TP-B, TP-B4
Finnerty, Matt	CP-IP07
Foster, Thomas	TP-D, TP-D3
Franklin, Scott	CP-TR01
Gire, Elizabeth	CP-AI03
Gray, Kara	CP-MT07
Grillo, Edward	CP-MT22
Hake, Richard	CP-GI01
Harlow, Danielle	CP-IP06
Harper, Kathleen A.	CP-IP07, TP-D, TP-D5
Heckler, Andrew	CP-MT08
Heller, Kenneth	CP-TR03, W-D
Heller, Particia	W-D
Henderson, Charles	CP-IP08, TP-B1, TP-D3
Heron, Paula	TP-A, TP-A1
Hestenes, David	W-B
Hieggelke, Curtis	CP-IP09
Hines, Aaron	CP-AI04
Hinrichs, Brant	CP-IP10
Hodari, Apriel	TP-B3
Horton, George	CP-MT03
Hrepic, Zdeslav	CP-AI05
Hsu, Leonardo	CP-TR03, TP-D1
Jennings, Sybillyn	CP-MT12, CP-TR07
Jones, Barbara	CP-AI03
Kaminski, Jennifer	CP-MT08
Kanim, Steve	CP-IP09
Kim, Yeonsoo	CP-MT10
Kim, Yeounsoo	CP-AI06
Kohl, Patrick	CP-IP05, CP-IP11
Kohlmyer, Matthew	CP-TR04
Koleci, Carol	CP-MT09
Krane, Kenneth	CP-MT19
Lee, Gyoungho	CP-MT10
Li, Pengfei	CP-TR05, CP-IP12
Lin, Yuhfen	CP-AI07, CP-AI13, CP-GI02
Lindblom, Joakim	W-B

Name – Last, First	Presentation Number
Lindell, Rebecca	CP-AI04, CP-AI08, CP-TR01
Loverude, Michael	CP-DM06
Maloney, David P.	CP-IP09, TP-D, TP-D4
Marx, Jeff	CP-IP13
Mateycik, Fran	CP-MT12, CP-TR07
McBride, Duncan	Luncheon Banquet Speaker
McCaskey, Timothy	CP-AI09
McGinnis, J. Randy	CP-GI03
McKinnon, Mark	CP-IP14, TP-E1
Meltzer, David	CP-DM04, TP-A2, TP-C3
Menchen, Katherine	CP-DM07
Messina, Donna	CP-IP04
Mestre, Jose	Invited Talk
Mian, Shabbir	CP-IP13
Morgan, Jeffrey	CP-AI10
Morote, Elsa-Sofia	CP-MT15
Morse, Robert A.	CP-IP15
Murthy, Sahana	CP-IP16
Mzoughi, Taha	CP-TR06
Nguyen, Ngoc-Loan	CP-DM04
Novodvorsky, Ingrid	RT-02
O'Kuma, Thomas	CP-IP09
Otero, Valerie	CP-IP06
Ozimek, Darryl	CP-MT13
Pagonis, Vasilis	CP-IP13
Park, Jiyeon	CP-MT10
Perkins, Katherine	CP-AI01, CP-AI11, CP-IP05
Podolefsky, Noah	CP-MT14
Pollock, Steven	CP-AI11, CP-IP17
Potter, Gregory	TP-E1
Potter, Wendell	TP-E, TP-E1
Price, Edward	CP-AI03, TP-B2
Pritchard, David	CP-MT15, CP-TR08
Raduta, Cristian	CP-DM08
Reay, Neville	CP-IP12, CP-TR05
Rebello, N. Sanjay	CP-AI05, CP-MT04, CP-MT07, CP-MT11, CP-MT13
Redish, Edward F. (Joe)	CP-GI03, TP-A3
Reilly, Paul	CP-AI12
Rivera, JJ	CP-MT12, CP-TR07
Rosengrant, David	CP-MT16
Sadaghiani, Homeyra	CP-MT17
Sandifer, Cody	CP-IP18
Sayre, Eleanor C	CP-MT18
Schwartz, Daniel	Invited Talk
Seggev, Rachel	CP-MT21
Sharma, Manjula	Invited Talk
Sherwood, Bruce	CP-AI02, CP-TR04
Singh, Chandralekha	CP-AI12, TP-C, TP-C1
Sloutsky, Vladimir	CP-MT08
Song, Wenjuan	CP-TR06
Stetzer, MacKenzie	CP-IP04
Stonebraker, Stephen	CP-IP03
Thaden-Koch, Thomas	W-D
Thompson, John R.	CP-DM07, CP-DM05
Turner, Warren	CP-MT09
Van Heuvelen, Alan	CP-IP19, CP-MT03, CP-MT16
Wagner, DJ	CP-MT12, CP-TR07
Warnakulasooriya, Rasil	CP-MT15, CP-TR05, CP-TR08
Warren, Aaron	CP-IP19
Wattanakasiwich, Pornrat	CP-MT19
Wieman, Carl	CP-AI01, CP-AI11
Williams, Benjamin	CP-IP20
Wittmann, Michael C.	CP-AI10, CP-MT20, CP-MT18, CP-DM05
Wulsin, H. Wells	CP-IP15
Yerushalmi, Edit	CP-MT21, W-D
Zollman, Dean	CP-AI05, CP-MT11
Zou, Xueli	CP-AI07, CP-AI13

Contributed Poster Room Layout

Union Ballroom – II

Contributed Poster Presenters: Please put up your poster on the board assigned to you.



LEGEND

‖ = 8' wide x 4' high Poster board.
Both sides usable. Each side shared by two posters.

X = Empty spot on poster board to accommodate post-deadline poster that can be placed in nearby category. Both sides usable. Each side shared by two posters.

The poster boards face each other and are 8 feet apart.

One end of each poster board is about 4 feet away from the closest wall.

PERC 2004 Organizing Committee

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