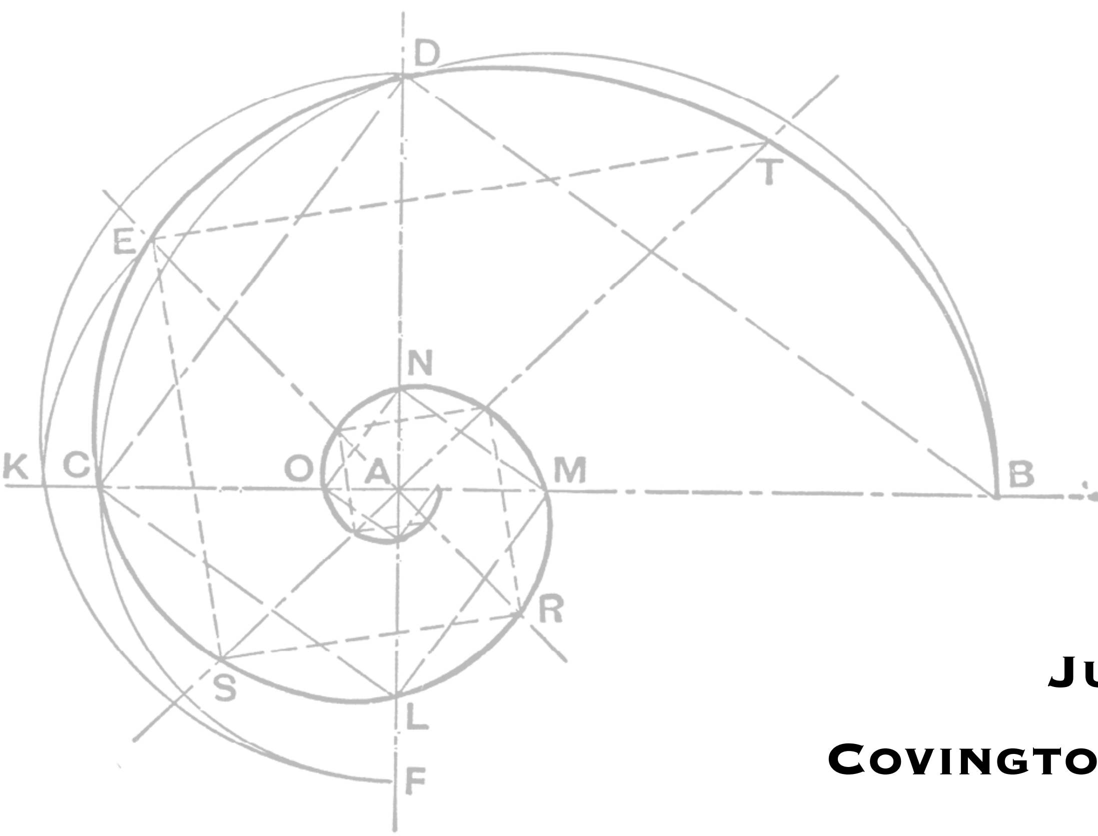
2017

Physics Education Research Conference

Mathematization and Physics Education Research



July 26th -27th

Covington, Kentucky

Physics Education Research Conference 2017

Conference Theme:
Mathematization and Physics Education Research

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

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

The proceptual divide is evident in physics courses, where success depends on having a proceptual understanding of both the prerequisite math and the learned physics. For example, Brahmia and Boudreaux, and Kanim (Brahmia and Boudreaux 2016, Kanim 1999) report on obstacles that many calculus level students encounter reasoning about the basic arithmetic relationships implicit in physics quantities. Rebello *et al.* (2007) observed that most introductory physics students approach symbol-rich physics problems that involve calculus or trigonometry as a procedure, framing their task as one of answermaking instead of sensemaking.

Conference organizing committee

Steve Kanim (New Mexico State University)
Suzanne White Brahmia (University of Washington)
Michael Loverude (California State University Fullerton)
John Thompson (University of Maine)

At-A-Glance Program Guide and Table of Contents

Wednesday, July 26th

Thursday, July 27th

(Many titles in this table are somewhat abbreviated. Full titles are given in the session descriptions.)

Wednesday, July 26th, 2:00pm Event Center II
Plenary Session

Michael Oehrtman, Oklahoma State University

Quantitative reasoning and mathematical modeling in an introductory calculus sequence

I will report on thematic results drawn from multiple studies of student learning in an introductory calculus sequence pertaining to the nature and roles of quantitative reasoning and mathematical modeling. We investigated calculus students' development of mathematical expressions and equations involving derivatives, definite integrals, and vector-valued functions to represent physical quantities and relationships between those quantities. The presentation will characterize the cognitive challenges that students encountered while constructing these models, how students resolved those challenges, and the resulting conceptual artifacts.

Michael Oehrtman is the Noble Professor for Technology Enhanced Learning in the Department of Mathematics at Oklahoma State University. Dr. Oehrtman was co-PI for Project Pathways, an NSF Math and Science Partnership to develop and implement research-based support for secondary mathematics and science teachers, integrating content across STEM fields. He continues research on teacher professional development as PI on the INFORMS MKT Project to study the mathematical knowledge expert teachers use throughout the planning, implementation, and assessment of their instruction and how that knowledge impacts their instructional decisions. He collaborated on the development and validation of the Precalculus Concept Assessment (PCA) that is now used for research and evaluation purposes by projects nationwide and served as the model for the current MAA Calculus Concepts Readiness Exam. His research on calculus students' reasoning formed the foundation of his Project CLEAR Calculus, coherently developing core concepts in the course while maintaining both rigor and conceptual accessibility. Dr. Oehrtman has served in numerous leadership positions for the Special Interest Group of the Mathematical Association of America on Research in Undergraduate Mathematics Education (SIGMAA on RUME) over the past decade, and currently serves in state and national leadership roles to support reform of remedial and gateway mathematics preparation of college students.

Wednesday, July 26th, 2:00pm Event Center II
Plenary Session

Megan Wawro, Virginia Tech

Student Understanding and Symbolization of Eigentheory

Linear algebra is a key course in students' undergraduate education across multiple STEM-related majors. Eigentheory is a conceptually complex idea that builds from and relies upon multiple key ideas in mathematics, and its application is widespread in mathematics and beyond. In this presentation, I will share research results from individual interviews regarding various ways that students in quantum physics courses reason about and symbolize eigenvectors and eigenvalues for a 2x2 matrix. I will also share an instructional sequence from the Inquiry-Oriented Linear Algebra curriculum created to support students' reinvention of change of basis and eigentheory, as well as how the two are related through diagonalization. Data from introductory linear algebra classes using this sequence will illustrate ways in which students build from their experience with stretch factors and directions to create for themselves ways to determine eigenvalues and eigenvectors for various 2x2 matrices.

Megan Wawro is an Associate Professor in the Department of Mathematics at Virginia Tech. Her research interests are in undergraduate mathematics education. Her research program includes investigating student thinking and instructional design in linear algebra, student understanding of mathematics in quantum physics, and methodologies for documenting mathematical reasoning at individual and collective levels. She earned a Ph.D. in Mathematics and Science Education from UC San Diego/San Diego State University, an M.A. in Mathematics from Miami University, and a B.A. in Mathematics from Cedarville University. Prior to her graduate work, she was a high school mathematics teacher in both Ohio and Switzerland.

Wednesday, July 26th, 3:30pm First Floor Lobby
Break and Poster Setup

Wednesday, July 26th, 4:00pm Event Center I
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Thursday, July 27th, 9:00am Meeting Room 6
Parallel Session 1A: Juried Talks & Invited Posters: Labs

Juried Talk 1

Impact of grading practices on students' beliefs about experimental physics

Bethany Wilcox, Colorado School of Mines, brwilcox@mines.edu
Heather Lewandowski, University of Colorado, lewandoh@colorado.edu

Student learning in undergraduate physics labs has been a growing area of focus for the PER community. Lab courses have been cited as critical elements of the undergraduate curriculum, particularly with respect to improving students' attitudes and beliefs about experimental physics. Previous work in lab learning environments has focused on the effectiveness of curricular innovations or changes to pedagogy; however, one aspect of the learning environment that has not be investigated is the impact of grading practices on students' beliefs and practices. We explore the possible link between students' perceptions of what is valued and rewarded by course grades and their beliefs about the nature and importance of experimental physics as measured by the Colorado Learning Attitudes about Science Survey for Experimental Physics. We find a significant correlation between students' perceptions of the value of certain activities and their personal epistemologies with respect to those activities.

Juried Talk 2

Examining students' personal epistemology: the role of physics experiments and relation with theory

Dehui Hu, Rochester Institute of Technology, dxhsps@rit.edu
Benjamin Zwickl, Rochester Institute of Technology, Ben.Zwickl@rit.edu

We investigated students' epistemological views of physics with a specific focus on physics laboratory work. The roles of experiments in physics have been underemphasized in previous epistemology research and there is a need for a broad view of epistemology that systematically incorporates experiments into discussions about the structure, methodology, and validity of scientific knowledge. An epistemological framework incorporating these features guided the development of an open-ended survey, which was administered to students in algebra-based and calculus-based introductory physics courses, an upper-division physics lab, and physics Ph.D. students. We identified several differences in students' epistemological views of physics. Regarding the roles of experiments in physics courses, introductory students viewed experiments as supplemental tools for conceptual learning and problem solving, while higher-level students valued unique things experiments provide, including experiments as opportunities to emphasize the empirical nature of physics and the development of scientific and professional skills. Regarding views on the relationship between theory and experiment, introductory students heavily emphasized experiment testing theory. However, higher-level students recognized a holistic cyclical relationship: experiment inspires theory, theory guides experiment, experiment tests theory, and theory explains experiment.

Thursday, July 27th, 9:00am Meeting Room 6
Parallel Session 1A: Juried Talks & Invited Posters: Labs

Invited Poster 1

A Pre-service Teacher Education Project: Developing and Teaching IOLab Activities

Rebecca Rosenblatt, Illinois State University
Raymond Zich

This study investigated the impact of a new lab design project on pre-service teacher preparation. Students enrolled in Illinois State Universitys junior level physics technology and teaching course completed a five-week lab design project. This project had them build a lab which would teach Newtons Laws using IOLab technology. The project guided the pre-service teachers through the major steps of curriculum design and culminated in their teaching the labs they created in a general education physics course. We will present a brief summary of TPACK and the basic education theory behind this project, the development stages for the project, the difficulties encountered in implementing this class project, summaries of the labs created by the pre-service teachers, the learning gains and survey results from the general education students who did the labs, and reflections on the project as a whole for teacher preparation.

Invited Poster 2

Development of Student Abilities in Control of Variables at a Two Year College

Krista E. Wood, University of Cincinnati
Kathleen Koenig, University of Cincinnati; Lindsay Owens, University of Cincinnati;
Lei Bao, The Ohio State University

Scientific reasoning skills are necessary for scientific literacy. The control of variables (COV) sub skill is foundational for developing scientific reasoning skills. This study investigated student development of low, intermediate, and high COV skills in a first semester algebra-based introductory physics lab at a two-year college. Nine COV questions were utilized to determine how students developed at the three COV skill levels. Findings indicated students' overall COV skills improved, but the increases varied according to the COV skill level assessed. These findings provide a baseline for a two-year college population for which scientific reasoning is largely unstudied. Future research will explore COV development at a four-year institution where a larger sample is available in order to inform future lab curriculum development.

Invited Poster 3

Impact of experience and equipment on student responses to open-ended dorm room experiments

Katherine Ansell, University of Illinois at Urbana-Champaign
Mats Selen, University of Illinois at Urbana-Champaign

At the University of Illinois, we have been engaged in lab reform at the introductory level which includes prelab assignments where students do simple physics experiments in their dorm rooms using the Interactive Online Laboratory (IOLab) system. In several of these assignments, students answer open-ended questions where they are given the freedom to choose what is important or interesting about their experimental data. We expect that as students grow accustomed to the prelab format and become more familiar with the IOLab equipment the quality and depth of their answers to these questions would improve. In two studies, we have investigated the impact of semester experience and equipment training on how students respond to open-ended prelab prompts for simple physical scenarios. This poster will describe these studies and their outcomes from comparing student responses from early and late in the semester and with varied equipment training conditions.

Thursday, July 27th, 9:00am Meeting Room 6
Parallel Session 1A: Juried Talks & Invited Posters: Labs

Invited Poster 4

Interview Validation of the Physics Lab Inventory of Critical thinking (PLIC)

Katherine Quinn, Cornell University
Carl Wieman and Natasha Holmes

Although a vital component of introductory physics labs is the way they train students in scientific reasoning and critical thinking, currently there are no commonly accepted standard tests in physics designed to assess such skills. We are in the process of developing and validating the Physics Lab Inventory of Critical thinking (PLIC), designed to assess students' critical thinking in introductory college level physics lab courses. The instrument asks students to critique a set of experimental methods and data and use them to evaluate a particular physical model (the period of a mass on a spring). Currently, we are validating our closed-response survey through interviews with students and present the results of 11 such interviews here. We describe a trend that has emerged from these interviews, with students' reasoning falling into several main patterns of behavior.

Invited Poster 5

Investigating student understanding of bipolar-junction transistor circuits

Kevin L Van De Bogart, University of Maine
MacKenzie R. Stetzer, University of Maine

As part of an ongoing effort to investigate the learning and teaching of analog electronics in physics and engineering courses, we have been examining student understanding of common bipolar junction transistor (BJT) circuits. Many of these circuits are quite complex, and we have found that most students are unable to analyze circuits derived from the common-emitter amplifier. As a result, we developed a suite of research tasks, often involving either simplified or modified circuits, in order to better probe and document the limits of student understanding of the behavior of BJT circuits. Findings from several of these tasks, as well as specific examples of student work, will be presented and implications for instruction will be discussed.

Thursday, July 27th, 9:00am Meeting Room 6
Parallel Session 1A: Juried Talks & Invited Posters: Labs

Invited Poster 6

A large-enrollment course transformation centered on ISLE labs: learning objectives help develop a shared vision with non-PER faculty

Debbie Andres, Rutgers University
Chaz Ruggieri, Suzanne Brahmia, Eugenia Etkina

Rutgers University has just completed its second year of a transformation of its introductory calculus-based physics sequence and the associated labs - involving ~800 students per semester - from a traditional structure to one that includes ISLE-based labs. The unusual feature of this transformation is that the lab, which had previously been a separate course, is now central to the course structure, and this happened through a bottom up change strategy. The change strategy has been one of developing a shared vision, both at the department level and at the level of the team of more than ten faculty and staff members responsible for teaching the courses. In this poster we discuss the process of collaboratively developing learning objectives, from which emerged a shared recognition of the central role that the ISLE laboratory experiences play in meeting the learning objectives the faculty articulated as being important to their personal teaching objectives. We describe the large-scale lab transformation that is in progress. Specifically we outline the steps we undertook transforming the labs, share student learning data obtained from lab reports, lessons learned from both activities, and future plans. Three important outcomes are: (1) for a transformation on this scale, there must be a departmental commitment to continuous and appropriate professional development of the lab instructors, (2) instructors need to be committed to the changes and ready to invest time in training, and (3) traditional assessments should be modified; it is important to build into the course grading system measures that reflect the learning objectives that the teaching team has agreed on and value. This outcome reinforces the need in the PER community for validated measures that align well with faculty-constructed learning objectives.

Invited Poster 7

Examining how physics lab practices influence a student's physics identity

Kelsey Funkhouser, Michigan State University
Marcos D. Caballero, Michigan State University
Vashti Sawtelle, Michigan State University

Using the communities of practice framework we are working to develop a survey to investigate how students' physics identities are affected by physics laboratory courses. How someone views themselves with respect to physics and the practices of the physics community is defined as their physics identity. Laboratory courses are intended to be opportunities for students to engage in authentic lab practices. This sort of participation can improve students' experiences, views of physics, and in turn their physics identity. As a first step, we are looking at how traditional physics lab practices influence a student's physics identity by analyzing how students talk about specific practices and how they position themselves with respect to those practices. Students can acknowledge that something is important for doing physics but distinguish the fact that it is not important to them personally.

Thursday, July 27th, 9:00am Meeting Room I
Parallel Session IB: Talk Symposium – Contrasting Cases

Contrasting Cases and Invention Activities in PER: Grounding Students' Understanding of Conceptual and Mathematical Relations in Physical Contexts

Recent research has demonstrated the learning benefits of having students generate their own representations and explanations of phenomena. This session will showcase the use of contrasting cases to guide student-generated connections between mathematical structures and physics problem contexts. Contrasting cases are sets of examples having a common underlying structure but varying surface features. The structure can highlight mathematical rules, physical concepts, or problem-solving approaches. Typically, learners examine the cases to generate a rule or index that represents the underlying structure. Contrasting cases provide a basis for testing predictions, and show the range of situations to which rules should apply. In this symposium, the speakers will describe different approaches to using contrasting cases and invention activities to promote deep understanding. The talks will span classroom and laboratory settings, discuss various principles for design and implementation, and illustrate how contrasting cases can help students learn mathematical principles in physics.

Presentation 1

Choosing the right examples: How contrasting cases can affect learning and future learning

Nicole Hallinen, Temple University
Daniel L. Schwartz, Stanford University

Inventing with contrasting cases is effective for helping students notice functional relations. However, instructors may need more guidance about selecting cases for instruction. In two-factor relations, cases could show main effects of each variable or their interaction. In a series of studies, community college students invented explanations for two-dimensional inelastic collisions. Some received cases isolating main effects, which led to a qualitative understanding. Others who saw cases where mass and speed trade off were more likely to find a multiplicative solution, receiving higher posttest scores. On a transfer task, all participants received balance scale contrasting cases showing enough variation that qualitative rules would not be sufficient. Participants who used the simplified momentum materials learned less from the transfer balance scale cases, even performing lower than control students who did not do the momentum activity. I will discuss the effects of contrasting cases on both learning and transfer to future learning.

Thursday, July 27th, 9:00am Meeting Room I
Parallel Session IB: Talk Symposium – Contrasting Cases

Presentation 2

Using contrasting cases to support strategic mathematization: Coordinate system rotation

Thanh K. Lê, University of Maine
Jonathan T. Shemwell; MacKenzie R. Stetzer

Being strategic when mathematizing physical situations is an important part of thinking like a physicist. Otherwise, students may be guided by surface features, resulting in non-optimal mathematization decisions. We investigated how students can learn to optimize the rotation of a coordinate system in static equilibrium problems to yield the simplest mathematical expression, despite surface features suggesting non-optimal rotation. In an experiment, introductory physics college students used contrasting cases to abstract a rule for strategic rotation that would be independent of surface features. There were two sets of cases. After a pretest, half of the students processed one set of cases, while the other half processed both sets. On a post-test, all students improved in their ability to strategically optimize coordinate rotation, despite distracting surface features. Students who processed both sets of cases made larger improvements. Our results suggest that students learned to separate strategy-guiding information from distracting surface features.

Presentation 3

A Distant Look at a Water Lily Pond: Inventing Physics Rules from Interactive Simulation or Contrasting Cases

Shima Salehi, Stanford University
Martin Francis Keil, Stanford University; Eric Kuo, University of Pittsburgh;
Carl Wieman, Stanford University

Studies show that having students attempt to invent a scientific rule before receiving direct instruction benefits their learning. However, "what kinds of invention activities aid learning?" is a question subject to further research. Here, we compare two different invention activities for learning about buoyancy. In one treatment condition, students explored a PhET simulation to invent a buoyancy rule. In another condition, students invented the rule from several contrasting cases of objects sinking or floating in a fluid. In general, students using contrasting cases invented more complete rules and performed significantly better in solving buoyancy problems. In the simulation condition, students risked not exploring all of the simulation's features, inventing a solution before they'd seen all facets of a phenomenon. These results show that the benefits of invention activities depend on scaffolding that helps expose students to the underlying structure of a phenomenon.

Thursday, July 27th, 9:00am Meeting Room I
Parallel Session IB: Talk Symposium – Contrasting Cases

Presentation 4

Impact of Various Contrasting Case Scaffolds on Students' Problem Solving

Marianna Lamnina, Teacher's College, Columbia University
Helena Connolly, Teacher's College, Columbia University; Vincent Aleven, Carnegie Mellon University; Catherine C. Chase, Teacher's College, Columbia University

This work explores ways to scaffold Invention activities to facilitate productive exploration of ratio structures in physical science equations, the goal of which is to prepare students to learn from later expository instruction. We have developed the first computerized Invention Coach that provides adaptive guidance as middle school students work through Invention tasks. This talk will discuss the rationale behind our novel pedagogical model, which draws upon empirical studies of human teachers guiding Invention and earlier prototype versions of our Coach, as well as prior research on the core learning processes that Invention promotes. Preliminary findings from a classroom study of the Invention Coach shed light on the process of guided Invention and provide some evidence of the system's efficacy in enhancing conceptual learning and transfer.

Presentation 5

Promoting Student Mathematization using Physics Invention Tasks

Andrew Boudreaux, Western Washington University
CSuzanne White Brahmia, University of Washington; Stephen E. Kanim, New Mexico State University

Physics experts develop ideas through mathematization, reasoning that connects the physical and symbolic worlds. Research has shown that students often struggle with the idiosyncratic ways that mathematics is used in physics. Other work has shown that invention tasks can help students use math productively in science and statistics. This presentation describes our physics invention tasks, classroom activities designed to support construction of quantitative physics concepts and relationships and to prepare students to understand subsequent formal instruction. These tasks present contrasting cases, and ask students to invent a way to characterize the system according to some key property. We will share examples of physics invention tasks as well as assessment data from a preliminary study of the impact on student learning.

Presentation 6

Impact of Various Contrasting Case Scaffolds on Students' Problem Solving

Carina M. Rebello, Purdue University
David M. Beardmore, Purdue University; Bryce A. Towle, Purdue University

Prior studies reveal that both contrasting cases and argumentation tasks can support deeper learning and problem solving skills. Yet, studies suggest that appropriate scaffolds are needed for these instructional strategies to be successful. We investigate three alternative forms of writing prompts (similarities and differences, invent a unified explanation, and argumentation) for multiple cases that address the momentum and energy principles. These scaffolds were integrated within physics problems utilized during calculus-based physics recitations, and we assessed their impact on students' learning. Results suggest that prompts for identifying similarities and differences within cases tended to promote identification of surface features in ways that were irrelevant to solving all case problems. However, argumentation prompts to evaluate competing theories tended to support deeper understanding of underlying principles and appropriate application of principles.

Thursday, July 27th, 9:00am Meeting Room 2
Parallel Session 1C: Custom Format – Role of Humor

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

Session Organizers Sissi Li, California State University Fullerton; Luke Conlin, Salem State University

Discussant: Rachel Scherr
Moderator: Luke Conlin

When laughter happens in the physics classroom, it can be seen as a distraction, even if a pleasant one. But there are serious reasons to study humor in the physics classroom. Cognitive science has revealed how emotions play an integral role in cognition and learning. For students and instructors, humor can serve as an important tool for managing the conceptual and emotional dynamics of the physics classroom. For researchers, attending to humor can reveal subtle aspects of students' thinking, and can bring to light the diverse ways students engage seriously in physics, even as they are laughing. In this session, we will explore the use of humor in the classroom in productive and inclusive ways through presentations from researchers, hands-on data analysis, and a discussion of our perspectives and findings.

Presentation 1

An analytical lens on humor in teaching and learning physics

Luke Conlin, Salem State University
Sissi L Li, California State University, Fullerton

As instructors, many of us have tried to make use of positive emotion stemming from humor in the classroom to engage students in learning physics. We sometimes use humorous cartoons and jokes intended to connect students to the content in a fun way. But humor is more than just fun; it takes some conceptual understanding and personal/emotional investment to appreciate and enjoy the joke. Further, taking a learning activity in physics seriously may look different for learners from different backgrounds and cultures. Humor can also have subtle side-effects that support participation, shape social dynamics, and communicate attitudes about doing science and being scientists. In this introduction, we will motivate the need to study humor in our instruction and present frameworks and perspectives that attend to the cognitive, social, cultural and personal nature of humor in the classroom.

Thursday, July 27th, 9:00am Meeting Room 2
Parallel Session 1C: Custom Format – Role of Humor

Presentation 2

What's so funny? How analyzing humor lends insight into student thinking

Colleen Gillespie Nyeggen, Lick-Wilmerding High School

Teachers and researchers recognize the importance of attending to and building upon students' ideas. However, many have overlooked one of the most telling ways students express their ideas: laughter. We will analyze the laughter in a clip of a whole-class discussion in a high school physics classroom. There is significant variability in what triggers students' laughter and the purpose the laughter serves. At times, the laughter responds to bald disagreement and serves to dissipate tension. At other times, the laughter highlights conceptual inconsistencies and serves to correct the speaker. For example, the class laughs when a student reported purposefully changing factors that were supposed to serve as experimental controls. When the student self-corrects, he laughs along with the class. The analysis reveals the varied reasons for students laugher, the methodological challenges of discerning these reasons, and the insights such an analysis can provide teachers and researchers into students' thinking.

Presentation 3

"Because math": Navigating conceptual and personal tensions in group discourse

Erin Ronayne Sohr, University of Maryland College Park

We will examine a clip of a clinical focus group of upper-level physics majors discussing a problem on the particle in a box. In this clip, the group closes the conversational topic of linear algebra through a shared joke around their tentative, mathematical solution. Evidence of shared humor comes from the presence of shared laughter and a marked change in the group's interactional space; particularly physical orientation towards each other, turn-taking norms, and responses to each other's proposals. Analysis of the group's interaction shows that the joke functioned to both leave a conceptual query unresolved, as well as mitigate some tension experienced by the group. This analysis shows that it can be difficult to tease apart whether it is cognitive dissonance or emotional dissonance driving the discursive trajectory of the group, suggesting that both the cognitive and emotional content of student discussion be of equal concern for instructors and researchers.

Thursday, July 27th, 9:00am Meeting Room 3
Parallel Session ID: Poster Symposium – Access Network

Bridging Research and Practice in the Access Network

Session Organizers Gina Quan, University of Maryland; Joel Corbo, University of Colorado

Moderator Joel Corbo will present an overview of the network (see session abstract below), and then the audience will circulate throughout the posters.

The Access Network is a coalition of six university-based programs that advance equity and inclusion in STEM fields, with a focus in physics. While they differ in their implementations, these programs share a set of five core goals that together embody the network's values:
1. fostering supportive learning communities
2. engaging students in the process of doing authentic science
3. helping students develop professional skills
4. empowering students to take ownership of their education
5. increasing diversity and equity in the physical sciences
Access seeks to enhance the efforts of individual sites by cultivating intersite communication, developing best practices for launching and sustaining new programs, and facilitating the sharing of ideas across sites through a variety of Network-level activities. In addition to programmatic activities, Access member programs are also conducting foundational research on how students interact with the programs and develop a senses of community and ownership over their learning. This presentation presents an introduction to both the programmatic and planned research activities of Access at the network level and provides framing for the presentations from the individual sites that comprise the rest of the session.

Poster 1

The Chi Sci Scholars Program: Creating supportive, inclusive, learning environments for Chemistry and Physics Majors

Christopher Mallares, Chicago State University
Coauthors Fidel Amezcua, Felicia Davenport, Nicolette Sanders, Raquell Mason, Kristy Mardis, and Angie Little

Ensuring that all students who want to pursue degrees and careers in science can do so is an important goal of a number of equity programs in college STEM throughout the United States. The CSU Chi Sci Scholars (CSS) program began in 2014 as a result of a grant from the National Science Foundation S-STEM Program and builds on the specific strengths and needs of our population on the southside of Chicago. The overarching goal of CSU's CSS Program are to increase the number of students receiving degrees in Chemistry and Physics by building science identity, creating a supportive cohort of peers, and providing financial support . Because of the population we serve at CSU, an implicit goal of the CSU S-STEM Program is increasing the number of underrepresented students entering the Physical Sciences.

* Supported by the National Science Foundation (NSF DUE # 1356523), the Department of Education, the Illinois Space Grant Consortium, and the CSU Center for STEM Education and Research.

Thursday, July 27th, 9:00am Meeting Room 3
Parallel Session 1D: Poster Symposium – Access Network

Poster 2

Cultivating an Inclusive Community in Physics: How CU-Prime Supports Students in a Research-Focused Classroom

Katherine Rainey, University of Colorado, Boulder
Benjamin Pollard

CU-Prime is a student-led, diversity-focused, and community-oriented organization at the University of Colorado Boulder. Our goal is to improve the culture of physics through equity and inclusion, allyship, and education. Our program includes a one-credit course called "Fundamentals of Scientific Inquiry." Comprised of a diverse group of students, the course benefits those from under- and over-represented groups by supporting the development of communication, collaboration, and metacognition skills while providing student-driven research experiences in a low-stakes environment. With a small enrollment size and opportunities for interactive engagement, we provide an environment for students to meet other physicists and engage in a more authentic scientific experience compared to introductory physics courses. In addition to conducting their own research in the course, students attend accessible research presentations given by graduate students. This unique course and talk series aims to change the current idea of who does science and what it means to do it.

Poster 3

Supporting Community Building and Physics Practices in Undergraduate Research Experiences

Gina M. Quan, University of Maryland, College Park
Chandra Turpen, University of Maryland, College Park

We discuss the design and research of an undergraduate seminar that is part of Focus on Physics, the Access site at the University of Maryland, College Park. Within this seminar, undergraduate physics majors are paired with mentors on physics research projects and participate in weekly discussions about research. Core principles of the Access Network guided the design of this seminar, including engaging students in authentic disciplinary experiences and cultivating supportive and reflective communities. We highlight several key features of the seminar that embodied the design of this seminar. Using video data from student interviews, classroom observations, research mentor interviews, and research observations, we study how students' participation in the seminar impacted their long-term engagement in physics. Finally, we discuss implications for future research and programmatic design.

Thursday, July 27th, 9:00am Meeting Room 3
Parallel Session 1D: Poster Symposium – Access Network

Poster 4

Fostering Community, Agency, and Metacognition in IMPRESS

Scott Franklin, Rochester Institute of Technology

IMPRESS is an NSF-funded program to engage first-generation and/or deaf/hard-of-hearing students in metacognitive and reflective thought on issues pertaining to STEM content. IMPRESS has three components: a two-week summer experience for incoming students, a semester-long course "Metacognitive Practice in the Sciences", and a Learning Assistant program. IMPRESS works with students to develop an understanding of one's mindset, the existence and impact of stereotype threat and microaggressions, the importance of developing one's own identity and improving self-assessment. IMPRESS seeks to foster a sense of community and student agency. IMPRESS students are recruited into paid positions to develop and deliver subsequent year's offerings, serving as models and peer-mentors for the next cohort. Recently, IMPRESS students have formed a student-run club ADMIRE that seeks to bring metacognitive practice to a wider RIT student audience.

Poster 5

Bringing Research into the Physics Lab Course

Michael Levy
Hilary Jacks

Participating in research increases retention in the sciences. Physics programs do not include a real research component until late in the undergraduate curriculum. We present a case study of an authentic -- yet highly scaffolded -- scientific experience to mostly freshmen as we use small group learning to support the students through designing their own research question to designing, implementing, and analyzing the data for their own experiment. We sketch outcomes and our teaching method and outline points of improvement to guide future courses like ours. We also discuss group dynamics and our efforts at getting students to see their peers as resources: integration into a helpful social network is known to also lead to retention. Its time we took physics lab courses off rails and let students do more than just guess the approach and the answers expected by their teachers. Who knows, they might even have fun.

Thursday, July 27th, 9:00am Meeting Room 4
Parallel Session IE: Talk Symposium – Representations in QM

Mathematical representations in quantum mechanics instruction

Session Organizer and Moderator John Thompson, University of Maine

Quantum mechanics involves the use of several mathematical representations of varying levels of familiarity to students, including Dirac notation, that are central to linking the mathematical formalism to the physical concepts and phenomena. This session highlights research in physics and mathematics education on: the structural features of these representations and their relationship to student reasoning; student fluency with and between representations; and student choice of representation to use for a particular problem, including how some of these choices depend on the instructional sequence (i.e., spins first or position first).

Presentation 1

Quantum notations as computational tools

Elizabeth Gire, Oregon State University
Ed Price, California State University San Marcos

The formalism of quantum mechanics includes a rich collection of representations for describing quantum systems, including functions, graphs, matrices, histograms of probabilities, and Dirac notation. The varied features of these representations affect how computations are performed. For example, identifying probabilities of measurement outcomes for a state described in Dirac notation may involve identifying expansion coefficients by inspection, but if the state is described as a function, identifying those expansion coefficients often involves performing integrals. We have identified four structural features of quantum notations: individuation, degree of externalization, compactness, and symbolic support for computational rules. We will discuss how these structural features may or may not support student reasoning.

Presentation 2

Investigating Students' Meta-Representational Competence with Matrix Notation and Dirac Notation

Megan Wawro, Virginia Polytechnic Institute and State University
Kevin Watson, Virginia Polytechnic Institute and State University; Warren Christensen, North Dakota State University

In this report we share analysis regarding students' meta-representational competence (MRC) that is expressed as they engage in solving quantum mechanics problems that involve linear algebra concepts. The particular characteristic of MRC that is the focus of this analysis is students' critiquing and comparing the adequacy of representations, specifically matrix notation and Dirac notation, and judging their suitability for various tasks (diSessa, 2004). With data from semi-structured individual interviews, we created categories of types of MRC elicited during students' work on an expectation value problem and a normalization problem. During the presentation will we share examples of the various MRC categories from our data and explore the relationship between strong MRC and a student's understanding and symbolization of linear algebra concepts within quantum mechanics problems.

Thursday, July 27th, 9:00am Meeting Room 4
Parallel Session 1E: Talk Symposium – Representations in QM

Presentation 3

Mathematization of Matrices in Quantum Mechanics

Gina Passante, California State University Fullerton

Matrices play an important role in spins-first quantum mechanics (QM) instruction. In this instructional paradigm students are first introduced QM using two-state systems with a heavy reliance on bra-ket notation and linear algebra. The quantum mechanical state vectors can be represented by two-dimensional column vectors and operators can be represented by 2x2 matrices. In this work, we explore student fluidity with matrix representations in quantum mechanics. In particular, we look at student use, generation, and interpretation of vectors and matrices. The data is drawn from student responses to questions in the context of two-state spin systems and degenerate perturbation theory.

Presentation 4

Student use of different mathematical representations for expectation values of physical observables

Homeyra Sadaghiani, California State Polytechnic University, Pomona

As part of ongoing research to understand how students relate quantum mechanics concepts and formalisms, we are investigating student approach to calculating and interpreting quantum mechanical expectation values for physical observables in two different teaching paradigms: Spins First and Position First. More specifically, we are comparing the range of the various mathematical representations students use for formalizing the concept of expectation value and whether or not there is a more recurrent mathematical representation among students in the two paradigms. Analyzing students' written responses to a series of open-ended research questions and informal focus group discussions with students from each paradigm has given us some insight into the frequency and commonality of the various mathematical formalisms students use.

Thursday, July 27th, 10:30am
Coffee Break

Thursday, July 27th, 10:45am Meeting Room 6
Parallel Session 2A: Juried Talks

Juried Talk 1

The use of epistemic distancing to create a safe space to sensemake in introductory physics tutorials

Luke Conlin, Salem State University

In active engagement physics classrooms, students get opportunities to make sense of physics together through discussion. They do not always take up these opportunities, in part because of the risk of sharing their ideas and having them rejected by their classmates or the instructors. In this case study, I analyze videotaped discourse of a tutorial group's early discussions to investigate how students manage these risks in creating a safe space to sensemake. I find that the students and instructors alike rely on a common discursive resource – epistemic distancing – to share their ideas while protecting themselves affectively if others disagree. Epistemic distancing includes hedging, joking, deferring, and other discourse moves used to soften one's stance in conversation. I use video analysis to illustrate the effects of these moves on one tutorial group's initial sensemaking discussions. I then discuss implications for instructors wishing to encourage sensemaking discussions in their physics classrooms.

Juried Talk 2

Investigating and promoting epistemological sophistication in quantum physics

Jessica Hoehn, University of Colorado – Boulder
Noah Finkelstein, University of Colorado – Boulder

While the physics community has made significant strides to go beyond traditional conceptual and content mastery by focusing on student epistemologies, examinations of domain-specific epistemology have been less common in physics. This paper examines how students think of physics' connections to the real world in two different contexts: classical mechanics and quantum mechanics. We demonstrate domain-specific perspectives, show sophisticated reasoning by students (who hold different perspectives), and suggest that faculty perspective and instructional practices influence students' views.

Juried Talk 3

Mathematization and the "Boas course"

Michael Loverude, California State University – Fullerton

Research on the use of mathematics in physics has included empirical and theoretical studies. We consider the implications of these studies on the mathematical methods course offered by many physics departments, often referred to as the 'Boas course' after a common textbook. Surveys of students entering such a course suggest that for many students the math in introductory courses consisted primarily of plugging numbers in formulas and execution of algebraic or arithmetic procedures. Data suggest that despite experience with procedures, many students entering math methods do not make sense of mathematical ideas relevant to upper-division physics. As a result, students arrive ill-prepared for physicist math and sensemaking. Models of learning and learning transfer suggest strongly that students will not spontaneously develop these skills by performing procedural exercises. The math methods course presents an ideal opportunity to develop these skills by explicitly practicing them in physics contexts.

Thursday, July 27th, 10:45am Meeting Room 5
Parallel Session 2B: Talk Symposium – Math Sensemaking

Math for making sense or math for making answers?

Session Organizers Natasha Holmes, Eric Kuo, Nicole Hallinen, Daryl McPadden
Moderator Natasha Holmes

In physics, mathematics and representations more generally are used as tools with which physicists make sense of the world. Too often, however, students use these tools procedurally or because they were told to, not because they see the utility of the tool. In this session, we will discuss a few examples of research demonstrating how instructional moves can reinforce students' procedural mathematics use (math for the sake of math) or can shift students towards a physical interpretation of mathematics (math for sensemaking). This session will present and contrast views of sensemaking with math, using examples from a range of traditional and reformed introductory laboratory and lecture courses.

Presentation 1

Math as tools for sensemaking or answer making

Natasha G. Holmes, Cornell University

In physics labs, data and measurements are often analyzed to make sense of physical phenomena. In a lab course that introduced students to various data analysis tools, we have found differences in the ways students approach the tool use. In particular, students either use the data analysis tools as final actions to represent and summarize their experiments or they use them as stepping stones with which to make sense of the experiments thus far and make decisions about how to proceed. We have found that instruction can help shift students from one mode to the other, but this shift is quite sensitive. A cue introducing them to a new tool can stifle their creative decision making and return them to a "represent and summarize" mode rather than a sensemaking mode.

Presentation 2

Constraining mathematically-correct answers to physically-appropriate solutions: The role of sketching and problem-solving frameworks

Nicole R. Hallinen, Temple University
Zbigniew Dziembowski; Nora S. Newcombe

Many mathematics problems have multiple solutions. However, when math is situated in physical contexts, scientific concepts place constraints on the types of solutions that are appropriate. We define sensemaking with mathematics as using ideas from physics to constrain mathematically-appropriate solutions to scientifically-appropriate solutions. Using student work drawn from a second-semester physics course, we will show examples from a lens problem involving the quadratic formula. In this problem, two solutions are mathematically appropriate, but one solution magnifies the image while the other shrinks it. Given the physical context of the question, only one solution makes sense. We investigate the ways in which prompts to draw sketches and follow problem-solving frameworks affect students' likelihood of sensemaking with mathematics (rather than completing the quadratic formula). Findings suggest that asking students to draw a sketch may be an especially effective way to help students realize which answers are both mathematically correct and scientifically appropriate.

Thursday, July 27th, 10:45am Meeting Room 5
Parallel Session 2B: Talk Symposium – Math Sensemaking

Presentation 3

Equations as one-of-many representations in University Modeling Instruction

Daryl McPadden, Florida International University

Modeling Instruction emphasizes and treats equations as one representation (out of many) that students use to create a conceptual model, with the goal to promote coherence between the physical concepts, the mathematical equations, and the other representations in the model. In this talk, I will discuss the multiple ways that the instructors, curricular materials, and classroom discourse emphasize this perspective of mathematical equations. I will present survey data that shows that even with the emphasis of equations as one-of-many representations, Modeling Instruction students do not rely on equations any less frequently than lecture students. In addition, I will draw upon a case study interview that shows how Modeling Instruction students are not only using equations to find an answer, but are also using other representations (i.e. energy pie charts) to build their equations from a conceptual understanding and are using equations from multiple models to check their solutions.

Presentation 4

Developing coherence between math and concepts through a Mathematical Sensemaking curriculum

Eric Kuo, Stanford University

Although PER has promoted conceptual learning as a valued instructional goal, competence with calculations and knowledge of concepts still remain distinct in many instructional and assessment paradigms. In this talk, I will describe the foundational principles of a Mathematical Sensemaking (MS) curriculum designed to build coherence between math and concepts. I will provide specific examples of how these principles, which include (i) developing conceptual interpretations of equations and (ii) resolving disagreements between intuition, calculations, and concepts, were implemented in a large-lecture, introductory mechanics course. A comparison to traditionally-taught students on a common final exam will show how MS instruction changed students' problem-solving approaches. Specifically, MS students were more likely to leverage calculation-concept coherence in their problem solving for increased accuracy and efficiency. I will end by discussing the implications for what is meant by "sensemaking."

Thursday, July 27th, 10:45am Meeting Room 2
Parallel Session 2C: Talk Symposium - Mathematization

Mathematization in university level undergraduate physics courses

Session Organizers Dina Zohrabi Alaee, Kansas State University; Tra Huynh, Kansas State University

Moderator Eleanor Sayre

We will use different theories and different modalities to describe mathematization in undergraduate physics courses, introductory-level through senior-level. We investigate how introductory-level students learn to blend mathematical operations/tools with physics context to make sense of the physics quantities/physical systems and how upper-level students continue to develop these mathematization skills as they coordinate among multiple representations to create new ideas, "looking ahead" into their solutions, and think algorithmically and conceptually.

Focusing on the "simple" equal signs, we explore how students, faculty and textbooks unpack multiple conceptual meanings in different contexts. In an interview setting, using epistemological framing, we provide a coding scheme to explore how students seek for coherency in quantum mechanics with respect to the role of mathematics, intuitive knowledge, and experiment.

We introduce a framework that characterizes students' use of mathematical tools in physics problem solving and discuss students' difficulties around the use of these mathematical tools.

Presentation 1

Physics student, faculty and textbook use of equal signs

Scott Franklin, Rochester Institute of Technology
Dina Zohrabi Alaee

Multiple conceptual meanings can be associated with the "simple" mathematical equal sign. This sign can imply causality, define new physical or mathematical quantities, or assign numerical or variational values to symbols. These meanings are context-dependent, and can change even within a single presented calculation. We study how physics students, faculty and textbooks use equal signs in multiple, dynamic ways and look for areas of common usage or noteworthy dissonances.

Thursday, July 27th, 10:45am Meeting Room 2
Parallel Session 2C: Talk Symposium - Mathematatization

Presentation 2

Investigating students' use of mathematics in upper-division problem solving

Bethany Wilcox, University of Colorado at Boulder

Student learning in upper-division physics courses is a growing area of research in the field of Physics Education. Developing effective new curricular materials and pedagogical techniques to improve student learning in upper-division courses requires knowledge of what material students struggle with. Here, I will summarize the development and theoretical grounding of an analytical framework designed to characterize how students use mathematical tools and techniques during physics problem solving. This framework has been used to investigate student difficulties with multiple mathematical tools, including multivariable integration in the context of Coulomb's law, the Dirac delta function in the context of expressing volume charge densities, and separation of variables as a technique to solve Laplace's equation. Application of the framework has revealed a number of common themes in students' difficulties around these mathematical tools including: recognizing when a particular mathematical tool is appropriate for a given physics problem, mapping between the specific physical context and the formal mathematical structures, and reflecting spontaneously on the solution to a physics problem to gain physical insight or ensure consistency with expected results.

Presentation 3

A tight conceptual blend of physics context, symbols and operations: Example of Negative Work

Suzanne White Brahmia, University of Washington

Mathematizing in a physics course might be seen as using mathematical procedures to help uncover physics thinking, or in a math course as a great context to practice new mathematics. In this talk I will push back on both of these characterizations and argue that the math-physics relationship is deeper and more likely one of symbiotic cognition; each has an important, and essential, role to play in the conceptual development of the other. As an illustration, I will focus on quantification at the introductory level, where ~10^2 new quantities are introduced. Quantification underpins physics understanding and multiplicatively combines value, units, sign and direction to characterize the physical world.

I will describe research we've conducted using free response and multiple-choice items to investigate quantification in large-enrollment calculus-based physics courses, and share data that focusses on work as a signed scalar product. Our data suggest that students struggle to make sense of the meaning of the sign, and may not be thinking about the operation of multiplication as producing something that differs from its factors. We will describe how an epistemological "nudge" to mathematically frame their thinking in the question statement improved the quality of mathematical sensemaking about this product quantity.

Thursday, July 27th, 10:45am Meeting Room 2
Parallel Session 2C: Talk Symposium - Mathematization

Presentation 4

Investigating Learners' Coherence-Seeking in Quantum Mechanics

Vesal Dini, Tufts University

Classical mechanics challenges students to use their intuitions and experiences as a basis for understanding, in effect to approach learning as "a refinement of everyday thinking" (Einstein, 1936). In subjects like quantum mechanics (qm), students, like physicists, need to adjust this approach, in particular with respect to the roles that intuitive knowledge and mathematics play in the pursuit of coherent understanding (these are adjustments to aspects of their views of knowledge or epistemologies). To explore whether students of qm sought coherence with respect to intuitive knowledge, mathematics, and experiment, I systematically coded interview data from undergraduate students I recruited and interviewed several times over the course of a semester. Among the key findings included the surprising variation in coherence-seeking among the participants, as well as two key trends: (1) individual students' epistemologies were mostly stable within a given course and (2) students aware that their understanding of qm ultimately anchors in its mathematics tended to produce more coherent explanations and perform better in their courses. These findings are consistent with existing research on student epistemologies in qm and imply that students' coherence-seeking requires greater attention and emphasis in instruction.

Presentation 5

How students mathematize in upper-division physics theory courses?

Bahar Modir, Kansas State University
Nandana Weliweriya

We looked across undergraduate upper-division physic courses to investigate how students mathematize. We use different theories and methods to find insight into problem solving in physics courses. Using ACER framework along with network analysis to investigate how students' connect their ideas as they use mathematical tools while solving homework problems. More broadly, we developed a framework which models students' framing in math and physics, expanded through the algorithmic and conceptual space of students' problem solving. We then focused on students' strategies as they coordinate between multiple representations or "looking ahead" into the solution to connect their math and physics ideas more insightfully.

Thursday, July 27th, 10:45am Meeting Room 4
Parallel Session 2D: Talk Symposium – Graduate Admissions

Multiple perspectives on graduate admissions and diversity in physics

Session Organizer and moderator Deepa Chari

Developing graduate admission practices that embrace gender and racial/ethnic diversity may help to diversify the physics community. However, the physics community has consistently lagged other STEM communities in supporting and improving diversity at the graduate level (amongst other levels). Graduate admission practices have been identified as a significant barrier to diversification. In this talk symposium, we present a collection of studies that explore admission practices and diversity considerations in graduate physics. Our studies capture multiple perspectives on graduate admissions from undergraduate physics majors, physics faculty, admissions committee members, and unsuccessful graduate applicants. We highlight typical admissions practices as well as discuss the possibilities of improving admissions by understanding and explicating faculty mindset in graduate admissions. Also, we discuss successful under-represented applicants' initial experiences of enculturation in their respective departments. This symposium provides insight about graduate admissions and post-admissions to empower stakeholders to take informed and effective actions related to admissions.

Presentation 1

Examining undergraduate students' views of graduate admissions

Geoff Potvin, Florida International University, STEM Transformation Institute
Deepa Chari

Students' perceptions of graduate admissions processes (e.g. concerns about high application costs, perceptions of biased decision-making, financial risks involved, etc) may significantly influence students' choices towards graduate school, including the possibility of not even applying because of perceived barriers, especially for students traditionally marginalized from graduate physics. For students who nonetheless apply to graduate school, decisions about which graduate degree to pursue (MS or PhD) and which graduate school to choose may be influenced by socio-economic factors, career expectations and interests, and prior academic and research experiences. In this talk, we present the results of our analysis of the Post-Graduation Career Intentions (PGCI) survey. The PGCI was developed to understand, amongst other things, upper division physics majors' perceptions about admissions practices and graduate education. This survey captured data from over 1000 physics majors in academic year 2016-2017 from across the U.S.

Thursday, July 27th, 10:45am Meeting Room 4
Parallel Session 2D: Talk Symposium – Graduate Admissions

Presentation 2

Fixed and growth mindset in physics graduate admissions

Rachel E. Scherr, Department of Physics, Seattle Pacific University
Abigail Pershing, American Physical Society; Monica Plisch, Department of Education and Diversity, American Physical Society; Theodore Hodapp, Department of Education and Diversity, American Physical Society

In light of the evidence that standard physics graduate admissions practices tend to exclude women and racial/ethnic minorities from the discipline, we investigate (a) what students physics graduate programs seek to admit and (b) what practices are associated with these admissions goals. Analysis of interviews with physics faculty suggests that some seek to admit students that they judge to have innate physics talent, measured primarily by a student's undergraduate grades and scores on the GRE. These faculty members express an overall "fixed intelligence" mindset, in which intelligence is understood as an inherent capacity or potential. Others seek to admit students who they believe can grow into physics achievement with effort, evaluating applicants by measures that may include passion for physics, determination, and coping with adversity. These faculty members express an overall "growth mindset," in which intelligence is understood in terms of acquired knowledge and effort.

Presentation 3

Graduate students' enculturation in physics departments

Deepa Chari, Florida International University, STEM Transformation Institute
Geoff Potvin

Many members of the physics community have noted the importance of facilitating the adjustment of graduate students to the cultural and academic demands of graduate school and research. We study students' experiences at the beginning of their graduate studies to identify which practices are valued by students in their enculturation to their programs and to the physics community. We interviewed 14 first-year graduates from sites associated to the APS Bridge Program, a national effort to improve underrepresented students' participation in physics. Our analysis focuses on students' interpretation of their departmental culture, their social and professional relationships with faculty and other students, and the connections to their particular graduate school experiences. Amongst the findings we will report, we note that a strong sense of camaraderie amongst bridge students and bridge mentors was reported by many participants, and that participants report the high value they place on shared space to their enculturation.

Thursday, July 27th, 10:45am Meeting Room 4
Parallel Session 2D: Talk Symposium – Graduate Admissions

Presentation 4

Identifying barriers to diversity in graduate physics programs - Pre-admissions

Geraldine L. Cochran, Rutgers University
Erika E.A. Brown, American Physical Society; Theodore Hodapp, Department of Education and Diversity, American Physical Society

Historically, access to education in the U.S. has not been equitable. Furthermore, intersectionality, the interaction of multiple identities, results in educational experiences that vary widely for diverse groups of students with implications for the recruitment of future students. To better understand barriers to ethnic/racial minority students participating in graduate education a study has been conducted through the APS Bridge Program, a program designed to increase the number of ethnic/racial minorities earning PhDs in physics. In phase one of this study, we analyzed student responses to an application question regarding why they chose not to apply to graduate physics programs. To further understand the barriers identified in the first phase of this study, we interviewed nine participants in the 2016 Cohort of the APS Bridge Program. The results of this study have implications for a variety of stakeholders interested in broadening participation in graduate physics education.

Thursday, July 27th, 10:45am Meeting Room 3
Parallel Session 2E: Workshop – Operationalizing Identity

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

Session Organizers Brian Zamarripa Roman, University of Central Florida; Jacquelyn J. Chini, University of Central Florida; Angela Little, Michigan State University; Chandra Turpen, University of Maryland; Adrienne Traxler, Wright State University; Jacqueline Doyle, Florida International University

In our research, we frequently ask participants to disclose aspects of their identities through demographic questions. The ways that we operationalize identity, i.e. how we pose questions, collect responses, and analyze the data, may impact respondents and influence interpretations of the data available to researchers. One major consideration is our participants: checking boxes may feel stressful, generalizing, or mischaracterizing of identity elements that they consider important. Another consideration is the consumers of our research: how do our characterizations of participants reify or challenge problematic U.S. societal narratives? Yet, we must collect demographic information to address some research questions focused on diversity. This session will serve as a forum to discuss methods and guidelines for operationalizing identity, guided by current methods used by researchers, to develop and share best practices for quantitative physics education research on diversity. Aspects of identity discussed will be race, ethnicity, gender, sexuality, and disability.

Thursday, July 27th, 12:15pm Event Center II
Lunch

Lunch program: Recognizing Pioneers of Mathematization in Physics Education

Moderator: Suzanne White Brahmia
Speakers: Andrew Boudreaux, Ayush Gupta, and David Meltzer

Thursday, July 27th, 1:30pm Meeting Room 3
Parallel Session 3A: Poster Symposium – Emerging Scholarship

Emerging Scholarship

Session Organizers Suzanne White Brahmia, University of Washington; Steve Kanim, New Mexico State University; John Thompson, University of Maine; Michael Loverude, California State University, Fullerton

Moderator Steve Kanim

The conference organizers created this invited poster session as a way of highlighting notable emerging scholarship selected from the juried talk submissions.

Poster 1

"You either know it or you don't," but "it would be sucky if you just knew everything." Students' differing epistemological beliefs in calculus and physics

Anna Phillips, Tufts University

Students often take introductory physics concurrently with calculus, and the two disciplines are deeply intertwined. While students' epistemological beliefs in physics have been studied extensively, less work has examined their beliefs in calculus. Even less is known about how students' epistemological beliefs in physics and calculus may relate, interact, and shift together or separately. We report on results of two independent studies: one including interviews of calculus students, and one of introductory physics students. Across both studies, we found that students made statements consistent with an algorithmic view of calculus while also expressing a view of physics as about sense-making. Through close analysis of one physics student, we also show that it is possible for a student to shift from a novice-like view of physics to an expert-like one while maintaining a algorithmic view of calculus.

Poster 2

Multiple tools for visualizing equipotential surfaces: Optimizing for instructional goals

Elizabeth Gire, Oregon State University

We discuss an instructional activity designed to help advanced undergraduate physics students visualize the electrostatic potential using three different tools: a whiteboard, a pre-programmed Mathematica notebook, and a 3D surface model. We analyze the role of these tools in the instructional activity using Activity Theory as a guiding framework. We discuss how the tools interact with the other elements of the activity system to shape how the activity is enacted by the students and instructors. We see that although each of the tools may be used independently to achieve the object of the activity - to produce a plot of equipotential surfaces - each tool differently achieves the main instructional goals of the activity. The whiteboard draws students' attention to superposition. The Mathematica notebook highlights the 3D nature of the electrostatic potential. The surface model draws students attention to the trends of the potential function and the connection between the rate of change of the function and the spacing of equipotential curves. This discussion provides an example that can inform the development of curricula that include similar tools.

Thursday, July 27th, 1:30pm Meeting Room 3
Parallel Session 3A: Poster Symposium – Emerging Scholarship

Poster 3

Using calculations on qualitative problems and concepts on quantitative ones: Calculation-concept crossover as a new problem-solving assessment paradigm

Eric Kuo, Stanford University

A standard problem-solving mindset equates quantitative questions with calculation skills and qualitative questions with conceptual understanding. However, we propose that there can be benefits of violating this one-to-one mapping, crossing over to use calculations for qualitative problems and concepts for quantitative ones. Two assessment problems that invite calculation-concept crossover are described. These crossover assessments are used to illustrate the increased problem-solving benefits of a mathematical sensemaking curriculum, focused on developing coherence between students' calculation skill and conceptual understanding, over traditional physics instruction. These results demonstrate a new paradigm for assessing the benefits of calculation-concept coherence in physics problem solving.

Poster 4

Student Interpretations of Partial Derivatives

Paul Emigh, University of Washington

We present results from an investigation into how students interpret partial derivatives at different points in their undergraduate career. We gave a long-answer survey to students near the beginning of both a multivariable calculus and an upper-division physics class that asked them to explain the meaning of the derivative in three different contexts. The most common patterns in the student responses are reported and discussed using a concept image framework based on the work of Zandieh. We also note differences in the response patterns of the students in the math and physics courses and differences in how students interpret the derivative across different representations of functions.

Poster 5

Early indications of success of Faculty Online Learning Communities (FOLCs) in supporting the teaching of new physics faculty

Melissa Dancy, University of Colorado, Boulder

We report on a new model of educational reform, Faculty Online Learning Communities (FOLCs), that are based on providing and nurturing virtual communities of support for faculty engaged in learning about and implementing research-based teaching techniques. Data collected to date indicate that the FOLC model increases participants' willingness to try new techniques, helps build their confidence to work through difficulties, increases their level of reflection about their teaching, and is viewed by participants as a positive experience that is worthy of their time. We conclude that this model is a promising addition to reform efforts built on standard Development and Dissemination (D&D) models of change.

Thursday, July 27th, 1:30pm Meeting Room 4
Parallel Session 3B: Custom Format - Accessibility

Accessibility and Universal Design in Physics Education

Session Organizers and moderators Dimitri R. Dounas-Frazer, University of Colorado Boulder; Benjamin M. Zwickl, Rochester Institute of Technology; Jacquelyn J. Chini, University of Central Florida

Presentation 1

Creating Inclusive Physics Classrooms for Deaf and Hard-of-hearing Students

Stacey Davis, National Technical Institute for the Deaf
David Spiecker

Stacey Davis teaches physics and astronomy to associate level deaf students at the National Technical Institute for the Deaf and supports deaf baccalaureate students taking physics at Rochester Institute of Technology. David Spiecker is an upper-division physics major at RIT and also works as instructional support faculty at NTID. Through David's perspective as a deaf student and Stacey's perspective as a teacher, they will address some of the issues deaf and hard of hearing students face in mainstream physics classrooms (including lectures, active learning, and lab courses) and some of the common misconceptions about deaf students. In addition to sharing strategies to make classrooms and activities more deaf-friendly, which often benefit all students, the dialog should encourage physics education researchers to study learning and develop curricula to support an increasingly diverse range of students.

Presentation 2

Universal Design: Making Postsecondary STEM Accessible to ALL Students

Jillian Schreffler, University of Central Florida
Westley James; Eleazar Vasquez, III; Jacquelyn J. Chini

Students with disabilities have increasing opportunities to attend a four-year college or university. As more students with disabilities enter our physics classrooms, instructors need to have the right tools and skills to make their lessons accessible to all students. In architecture, the principle of "Universal Design" guides architects in planning for user variability by designing environments that are usable by all people without the need for adaptation or specialized design. Applications of Universal Design have been developed for education to support instructors in designing learning experiences that enable all learners to naturally engage with the course, reducing the need for accommodations. Just like all users, not just those with mobility impairments, benefit from a sidewalk "curb cut," Universal Design has the potential to better support learning by all students. This presentation will describe and provide examples of the Universal Design for Learning and Universal Instructional Design frameworks.

Thursday, July 27th, 1:30pm Meeting Room 4
Parallel Session 3B: Custom Format - Accessibility

Presentation 3

Increasing the Accessibility of PhET Simulations for Students with Disabilities: Challenges, Progress, and Potential

Katherine K. Perkins, University of Colorado, Boulder
Taliesin L. Smith, Emily B. Moore Perkins

The PhET Interactive Simulations project impacts classrooms around the world through over 130 interactive science and mathematics simulations and associated teacher resources. Despite the potential of PhET sims to foster engagement and participation in science education, they are currently inaccessible for many students with disabilities. This is due to the reliance on predominantly visual representations of concepts, and interfaces that rely on dexterity with a mouse or touch-screen device. In 2014, the PhET project began an initiative to increase the accessibility of our suite of HTML5 simulations for students with and without disabilities through the use of inclusive design. Over the past 3 years, we have overcome technical challenges, started a (growing) accessible simulation design community, developed prototypes of accessible PhET simulations (with keyboard navigation and auditory descriptions), and engaged in research of inclusive features with diverse students. In this presentation, we will highlight aspects of our work in accessibility and inclusion by: 1) sharing some of the challenges to accessibility faced by creators of dynamic, interactive content; 2) demonstrating accessible PhET simulation prototypes; 3) and sharing research findings on the use of accessible PhET simulations by students with visual impairments. We will end by briefly describing some upcoming accessibility features in development, and what these new features can enable in the classroom.

Presentation 4

When Students are Left in the Dark

Jamie Principato, Colorado Center for the Blind

Often in the postsecondary physics classroom, tradition shapes the way lessons are delivered and mastery is measured. All too often, these traditional delivery and examination methods leave students who have sensory disabilities in the dark. As a blind student, I have experienced first-hand the damage that is done when students and professors are unable to communicate with each other in an accessible medium, or when doing things the way they have always been done takes precedence over ensuring that every student has the opportunity to pursue and demonstrate understanding. As an undergraduate researcher, and the leader of a growing education initiative that puts the tools of a physicist directly into the hands of blind students, I also know that there is a better way. In this panel session, I will describe some of my own experiences studying physics, in the classroom and the lab, and I will share insights that I have gained through my outreach efforts.

Thursday, July 27th, 1:30pm Meeting Room 2
Parallel Session 3C: Custom Format – POC Discussion Space

People of Color Discussion Space

Session Organizers Alexis Knaub, Western Michigan University; Geraldine Cochran, Rutgers University

Safe spaces are especially important for marginalized groups. They often provide an opportunity for individuals in the group to utilize their agency to act and speak on their own behalf. They also aid in creating solidarity among the group. We propose to create a space for People of Color in physics education research as a session for the 2017 PERC conference. We envision this session providing an opportunity for People of Color to share stories, articulate their needs as members of the field, and get to know one another.

Thursday, July 27th, 1:30pm Meeting Room I
Parallel Session 3D: Talk Symposium – Non-Cartesian Vectors

Vectors and unit vectors in non-Cartesian coordinate systems

Session organizer and moderator Michael Loverude, California State University Fullerton

This session will present several studies examining student understanding of vectors and unit vectors in non-Cartesian coordinate systems. Throughout upper-division physics, students are required to reason in coordinate systems including plane polar, cylindrical, and spherical. Most students learn the fundamentals of vector notation in the context of Cartesian coordinates and have little specific instruction on how these ideas are generalized to other systems. Research has shown that generalizing from Cartesian coordinates is not simple for many students. Talks in this session will highlight aspects of the research, including studies to investigate student thinking and tasks designed to improve student understanding.

Presentation 1

Helping Students Make Sense of non-Cartesian Unit Vectors in Upper Level E&M

Brant E. Hinrichs, Drury University

An upper level E&M course (i.e. based on Griffiths) involves the extensive integration of vector calculus concepts and notation with abstract physics concepts like field and potential. We hope that students take what they have learned in their math classes and apply it to help represent and make sense of the physics. In 2010 we showed that students at different levels (pre-E&M course, post-E&M course, 1st year graduate students) and in different disciplines (physics, electrical engineering) had great difficulty using non-Cartesian unit vectors appropriately in a particular context. Since then we have developed a set of four linked problems that students work on in groups and discuss as a class, to help them confront and resolve some of their difficulties. This talk presents those problems, typical student responses, and three years of post-tests (given on quizzes or exams) that were used to assess their effectiveness.

Presentation 2

A tale of two differential length vector constructions in non-Cartesian multivariable systems

Benjamin Schermerhorn, University of Maine
John Thompson

Given the significance of vector calculus and non-Cartesian coordinate systems to physics understanding in junior-level Electricity and Magnetism (E&M), the course provides a rich context to explore student understanding and determination of multivariable differential vector elements. Two interview tasks were administered in which students construct differential length elements for a given scenario. In the first task, student pairs reasoned about an unconventional spherical coordinate system. While no pair initially constructed the correct length element, they paid particular attention to the need for multiple components to represent the multiple directions of possible motion. The second task, more aligned with typical E&M problems, asked individual students to determine a differential length vector to calculate the electric potential difference over a spiral path. In contrast to the previous task, students were more likely to acknowledge only the theta component of the differential length vector, ignoring the change in the r-hat direction.

Thursday, July 27th, 1:30pm — Meeting Room I
Parallel Session 3D: Talk Symposium – Non-Cartesian Vectors

Presentation 3

Investigating and addressing student ideas about coordinate systems in the upper division

Brian Farlow, North Dakota State University
Warren Christensen

Initial investigations have identified ideas upper-division undergraduate physics students bring to bear while attempting to solve non-Cartesian coordinate system problems. We identify specific resources for unit vectors, resources connecting polar vector elements to Cartesian vector elements, and the orthogonality of basis vectors in various coordinate systems. While not all of these resources are used productively by students, they constitute a set of ideas that can be explicitly addressed through instructional materials. We report on these findings as well as early development of instructional materials intended to promote productive student thinking about non-Cartesian unit and position vectors specifically among junior/senior-level undergraduate students.

Presentation 4

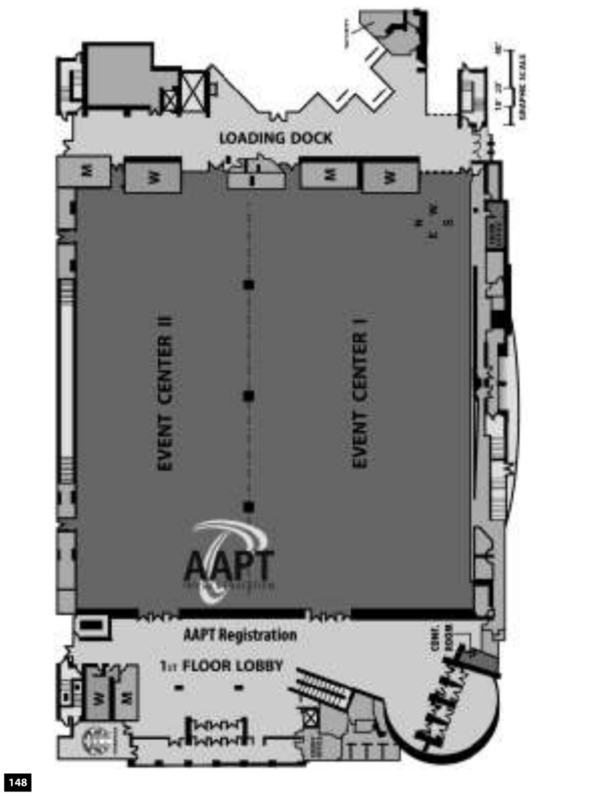
Student resources in polar coordinates

Marlene Vega, California State University Fullerton
Michael Loverude

In upper-division physics courses students work with various coordinate systems, but research has shown that students are less comfortable with non-Cartesian systems. This study began with a difficulties framework, in which we sought to document difficulties with non-Cartesian coordinates. However, we found that a resources framework allowed us to see more than just the difficulties students have. It allowed us to identify the different pieces of knowledge that the students assemble when answering these physics questions. This study aims to identify different resources students activate when answering questions in various contexts regarding unit vectors in polar coordinates. We will present data from written responses and interviews of students in upper division physics courses at two universities.

Thursday, July 27th, 3:15pm — Event Center II
Closing and Summary

Northern Kentucky Convention Center 1st floor



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