**Invited Talks**

**Smart Girls, Too Few Choices:  Why young women still steer away from science and math careers and what teachers can do about it**
Stephanie Blaisdell, Ph.D.
Consultant, Diversity in STEM Fields
Collierville, TN

Over the past three decades a huge emphasis has been made on getting girls “caught up” to their male counterparts in middle and high school math and science course selection and performance.  The great news is – we’ve succeeded!  Girls are now taking the same level of courses, and doing as well, as the boys.  Unfortunately, improving their academic preparedness for STEM (science, technology, engineering and math) careers has not greatly affected their behavior in choosing these careers.

This session will discuss the current trends in career choice for young women who are talented in math and science.  Why do they choose the fields they do, and what fields are they ignoring to their, and our, detriments?  How can math and science teachers at the middle and high school level help to bridge the gap from grades to career choice?  Current research, including marketing data from the Extraordinary Women Engineers Project, will be discussed.

**Process object theories of learning and applications to understanding first-order differential equations**
John E. Donovan II Ph.D.
Assistant Professor of Mathematics Education
University of Maine, Orono, ME

Findings from a study investigating the nature of students’ understanding of first-order differential equations will be the focus of this talk.  The data comes from two case studies.  The participants were studying first-order differential equations in a modern course on differential equations that emphasized multiple representations and solution methods.  The primary data sources were a series of four interviews designed to understand the participants’ meanings for different representations of differential equations.  During the interviews participants thought aloud while they:  sorted 20 functions and differential equations given on cards into meaningful groups; “told everything they could” about given differential equations; and solved non-routine tasks.  The contrast between the two case studies is stark, with one student knowing “what to do and why” and the other knowing “rules without reasons.”  Process/object theories about learning mathematics provide insight into the data and reveal the importance of a flexible, multi-representational understanding of functions and the duality of viewing a differential equation as an equation to be solved and a function.  The data also suggest how the first-order differential equation concept develops as a process on a structural understanding of the function concept.

**The physical sciences as a basis of integration: The Academy of Science model**
Jayne Fonash
Director of Guidance
Loudoun County Public Schools, Academy of Science, Sterling, VA

The mission of the LCPS Academy of Science is to provide an academic and nurturing environment where students are encouraged to develop creative scientific endeavors of their own design, while having the opportunity to pursue a rich, well-rounded high school experience.  Students will acquire skills to ask sophisticated scientific questions and conduct research and experimentation, to explore the interconnections between the sciences, math, and the humanities, to read, write, and communicate at a level that is required of university students, and to develop perspectives to assess the impact of scientific advancements on society.

Teachers are selected to be content experts as well as outstanding educators, and are assigned an advisory of incoming students to mentor through their four years at the Academy.

The cornerstone of science preparation is a 9th/10th grade integrated science program, which blends the physical sciences of physics, chemistry and earth science into a seamless, inquiry based lab course in preparation for AP coursework. The goal of the lab program is student designed investigations coupled to an in-depth writing/scoring rubric.  In addition, sophomores begin instruction in basic research technique to be followed by two years of research in a topic of their choosing.

The Math program offers courses from Algebra and Trigonometry through Multivariable Mathematics. All courses have a heavy component of statistics and modeling and are taught in terms of practical application in order to coincide with the science program.

**Native waters**
Ed Galindo Ph.D.
Research Scientist
Aquaculture Department- American Indians in Science
University of Idaho, Moscow, Idaho, 83844

This project is called Native Waters. This program model is taken from some research work I am currently doing with Native people in Montana, Nevada, Utah, and Idaho.

Water connects all people together. Water is life; water is sacred for all things that live on this planet.

Several important topics will be presented for consideration. For example, how water connects us, water stories, keepers of clean water, salmon, (stories of the finned one’s), downstream destinations of water, honoring wetlands, and finally, understanding the common ground we all need, respect for clean water.

The second theme, education will be used to understand and integrate traditional ways of knowing and scientific ways of knowing. We know today that most water resource problems are multidimensional.  Science alone cannot solve them.  The solution of solving water problems is one of changing attitudes and actions. Traditional knowledge includes knowing a place. It covers knowledge of the environment; for example, snow, ice, weather resources, and the relationship between all these things. Traditional knowledge is a holistic way of looking at the world. An Elder told me “We are finally getting to the point again where we can put our ancient knowledge to use in the modern world, side by side with Western science”. I feel this is am important story to tell.

In summary, Native Waters is an educational program dedicated to increasing awareness and respect for water resources (example, the Columbia River). This education and scientific initiative supports efforts of native and non-native community leaders, educators, elders, water managers, natural resource managers, and students to develop contemporary, scientifically accurate, and cultural sensitive water education resources, programs and networking opportunities.

This program may be of interest to teachers from elementary to graduate school. It is has many concepts that pertain to math and science. Come hear the story, it will be fun!

**What we know about preparing secondary science teachers: a few facts, many assumptions and great deal of unanswered questions.**
Nicole M. Gillespie, Ph.D.
Senior Program Officer, Science
Knowles Science Teaching Foundation

For many, the phrase “science teacher preparation” refers to the coursework and field experiences that are required by credentialing programs in schools of education.  In reality, however, the preparation of science teachers is a continuum that begins with undergraduate science content education and continues through the early “induction” years of teaching.   In this talk, I will discuss research that investigates how various aspects of science teacher preparation impact teacher quality, student achievement and teacher retention, highlighting critical questions that have yet to be answered.  Additionally, I will discuss the programs of the Knowles Science Teaching Foundation (KSTF) targeted at enhancing key areas of secondary science teacher preparation and will present preliminary results of the research on beginning science teachers that is being conducted by KSTF.

**College math and science performance and ethnicity: Some Recent Trends and Idea**
Eric Hsu, Ph.D.
Associate Professor of Mathematics
San Francisco State University, San Francisco, CA

Much work in the last three decades has been devoted to increasing the performance of minority students in college math and science. This talk surveys some of the results, issues and trends emerging in the last decade. Topics will include the ineffectiveness of introductory courses, stereotype threat, multi-racial identities, and changes in class composition within ethnic groups.

**The relationship of coherence of thought and conceptual change to ability**
Pamela A. Kraus, Ph.D.
Research Scientist
FACET Innovations, Seattle, WA

Students’ thinking in topics of force and motion seems to fit a perspective of “knowledge in pieces” (diSessa, 1985)   rather than specific Theoretical Models of thinking in physics. In most of our research the pieces (we call them “facets” (Minstrell, 1992) ) are constructions of one or more smaller pieces of experience or prior ideas. The facets of thinking applied to situations frequently vary depending on features of the situation, suggesting that students (especially younger or lower ability students) are inconsistent in their reasoning across contexts. Recently we have been mining our data to see if there might still be some coherence across contexts, (e.g. forces on objects while speeding up, moving with constant speed, and slowing down) and to see the extent of change in understanding through middle and high school. We will present our findings in this presentation.

diSessa, A. A. (1985). Knowledge in pieces. Berkeley: University of California.

Minstrell, J. (1992). “Facets of students’ knowledge and relevant instruction.” In R. Duit, F. Goldberg & H. Niedderer (Eds.), Research in physics learning: Theoretical issues and empirical studies (pp. 110-128). Kiel: IPN.

**Project Lead The Way: A solution to increasing student interest in math and science.**
Patrick Leaveck
Regional Director
Project Lead The Way, Davison, MI

Students more than ever ask: Why do I have to know this and when will I use it?   It makes sense that the more we can link coursework to real life, the more likely students are to retain and be able to use what they learn in school. The high school reform movement is based on the two principles of rigor and relevance.  More rigor is the easy part, and more relevance is not so easy.   Project Lead The Way is based on these two principles.  In this 25 minute session, learn how PLTW has brought rigor and relevance to high schools and middle schools across the nation.  As a not-for-profit organization, PLTW provides free curriculum which gives students hands-on experience applying math and science concepts to solve real-life problems. These problem-solving and analytical skills are central to the program, and are applicable to any career field.

**One step at a time: Working toward change in general chemistry**
Jennifer Lewis, Ph.D.
Assistant Professor of Chemistry
University of South Florida, Tampa, FL

This talk focuses on a curricular change undertaken in a large general chemistry course. We argue that curricular changes require robust evaluation methods focusing on both effectiveness and equity, and our initial findings will be provided. The curricular change itself draws from two national reform movements for college chemistry, Peer-Led Team Learning and Process Oriented Guided Inquiry Learning, and is known as Peer-Led Guided Inquiry.  Specifically, we have replaced one lecture per week with a peer-led small group guided inquiry session.  Students are divided into groups and, rather than going to the lecture hall on Fridays, meet in small rooms on campus at their assigned lecture time. Peer leaders for the Friday sessions are selected from a pool of undergraduates who have previously done well in general chemistry, and they participate in weekly facilitation training that draws from the principles of cooperative learning.

Support for this project has come from a National Science Foundation CCLI grant – #0310954.

**New integrative marine science courses at the University of Maine build skills through inquiry, writing, and critical thinking**
Sara M. Lindsay, Ph.D.
Assistant Professor of Marine Sciences
University of Maine, Orono, ME

Marine Science is a highly interdisciplinary field, and undergraduate marine science majors at the University of Maine complete a curriculum that includes introductory classes in biology, calculus, chemistry, earth sciences, ocean sciences, and physics. Because most of the core introductory classes are taught by other departments, until recently students had very few hands-on experiences relevant to marine science until they reached upper division elective courses. To better integrate marine science with the basic science curriculum, provide relevant hands-on experiences, and foster student inquiry and critical thinking at all levels, the School of Marine Sciences recently established a sequence of four Integrative Marine Science (IMS) classes. The IMS classes progressively expose students to more complex problems and deeper inquiry.

This talk will provide an overview of the IMS classes, the rationale behind them, challenges of implementation, and share success stories from the writing-intensive Integrative Marine Science Seminar and Integrative Marine Science: Physics and Chemistry classes. Two specific topics will be considered: assessment strategies that quantify student progress and changes in attitude toward writing; and integration among the classes to encourage deeper exploration and understanding of central topics.

**Connecting School and Community as a Way to Improve Alaska Native Students’ Math Performance**
Jerry Lipka Ph.D.
Professor
School of Educational Research, University of Alaska – Fairbanks

Math in a Cultural Context (MCC) is a complex action-research project which includes a long-term collaboration between faculty at the University of Alaska Fairbanks with Yup’ik elders and teachers, mathematicians and math educators, educators, and school districts. This project has been a success on multiple levels: repeated findings showing that classes that used MCC’s modules outperformed classes that used the curriculum in place and the long-term ongoing collaboration with a caste of unlikely partners.

This presentation includes a power point /video, showing subsistence activities that were basis for math activities in sixth grade classrooms.  Video footage of classrooms enacting MCC activities shows how we connected everyday activities into math activities.

The presentation ends with data, quantitative and qualitative, that shows the overall impact of MCC in closing the gap between rural Alaska Native students and their urban counterparts. Questions and discussion follow.

**Gender in science and math education**
Laura McCullough, Ph.D.
Science Education Program Director
Associate Professor, Physics Department
University of Wisconsin-Stout, Menomonie, WI

What is the status of girls and women in science and math at the K-12 level?  Is there a problem?  What might be done to make science and math more inviting to girls and other minorities? This talk will focus on the latest statistics and research on gender and science/math education.

**Obstacles to calculus: Difficulties with geometry and visualization**
David Meel, Ph.D.
Assistant Professor
Department of Mathematics and Statistics
Bowling Green State University, Bowling Green, OH

This talk will discuss some of the difficulties students face when exploring calculus concepts.  In particular, we will examine problems student have with geometric and visualization capabilities and how they impact their ability to grapple with particular calculus problems.  By using interviews with students looking at Pythagorean-based problems in the context of related-rates, students were found to come to the study of calculus with misconceptions and misunderstandings of geometry that directly impacted their ability to explore related rate problems.  In particular, students were found to have difficulty understanding requirements, visualizing change over time, interpreting appropriate solution strategies, extracting information from geometric figures in non-standard orientations, integrating multiple perspectives, visualizing in three dimensions, and applying the Pythagorean Theorem. This study confirms that students are lacking the adequate geometric skills that are necessary to solve such problems. In addition, spatial reasoning ability and its development is an important component that can assist or hinder problem solving. However, students are developing procedural knowledge rather than conceptual understanding of geometric topics resulting in weak schemas and mental models surrounding geometry unsupportive of their ability to succeed in calculus.

**Overview of The Board of Science Education**
Marguerite Murphy
Teacher and Board member BOSE
Georges Valley High School, Thomaston, ME

The Board on Science Education (BOSE) is a standing board within the National Research Council, the operating arm of the National Academies.   The National Academies incorporates the National Academy of Science, the National Academy of Engineering, and the Institute of Medicine. The Board resides in the Division of Behavior and Social Sciences and Education and is part of that Division’s Center for Education.

The Governing Board Executive Committee of the National Academies chartered the Board on Science Education in December of 2003.  This board formed from the need to have a well-coordinated and comprehensive voice on the whole of science education; preschool through graduate education, informal science education, as well as the public understanding of science.  By focusing on science education across the lifespan, the Board on Science Education can provide a more comprehensive response to the communities of policy, practice, and research.

**Development, implementation, and evaluation of an integrated lab-lecture format for undergraduate science courses.**
Maria T. Oliver-Hoyo, Ph.D.
Associate Professor of Chemistry
North Carolina State University, Raleigh, NC,27695

A traditional chemistry format consisting of three-hour per week lecture with accompanying three-hour lab periods has been transformed into three two-hour periods per week of hands-on activities where students work in collaborative groups and the instructor serves as the facilitator for learning. The Student-Centered Activities for Large Enrollment University Programs, better known as the SCALE-UP Project, fully integrates lecture and laboratory formats in physics, chemistry and biology courses. Pedagogies used in this innovative format have been tested in small classes, however, the SCALE-UP Project uses them in classes of up to 99 students. The project has investigated the classroom designs, classroom management techniques, and research-based curricula needed to make activity-based instruction effective for these large classes. This presentation will discuss common myths about student-centered instruction including time constraints, content coverage, activity efficacy, and roles of students and instructors. Studies conducted with SCALE-UP chemistry classes that show the benefits of this format in both cognitive and attitudinal gains will also be highlighted.

**Development of laboratories for introductory physics**
Luanna G. Ortiz, Ph.D.
Department of Physics and Astronomy
Arizona State University, Tempe, AZ

We have been investigating student understanding of kinematics in physics laboratory courses at several universities. At Arizona State University the focus of the research has been student performance on problems involving two-dimensional motion after completing a lab on projectile motion. In this presentation we will describe prevalent reasoning difficulties that appear to influence student predictions about the motion of a projectile. Results from individual student interviews and written questions will be presented. This research will inform the development of laboratory materials for use in the algebra-based physics course. The preliminary edition of the lab curriculum is under development, and will ultimately include fifteen labs on mechanics, including some that are a direct outgrowth of Tutorials in Introductory Physics by McDermott et al. (2001). This research has been supported in part by the National Science Foundation.

**Using technology in general chemistry homework and to assess problem solving skills**
Norbert J. Pienta Ph.D.
Department of Chemistry
University of Iowa, Iowa City, IA, 52242

Few chemistry instructors would argue about the value of homework, especially in introductory courses.  Technology now makes electronic versions particularly attractive in large enrollment courses-students practice their skills, they get feedback almost immediately, and the instructor’s (and when available, teaching assistants’) time can be used in other ways.  We will report on data we have collected about student participation and outcomes using a variety of products and strategies since 2000.  But what is the evidence that electronic or any homework improves student problem solving skills?  We have created web-based problems and a set of tools that track students’ attempts to solve them.  We will report on the use of neural network analyses and other statistical methods to track the pathways that define student approaches and outcomes.  Finally, we will present data and discuss the role of cognitive or memory load in homework or assessment (i.e., exam) questions.

**Implementation of the Model-Observe-Reflect-Explain (MORE) thinking frame in multiple contexts: effects on thinking and learning about chemistry**
Dawn Rickey, Ph.D.
Assistant Professor of Chemistry
Colorado State University, Fort Collins, CO

The Model-Observe-Reflect-Explain (MORE) Thinking Frame is an instructional tool that has been shown to promote better understanding of chemistry ideas when used in general chemistry laboratory courses.  Based on studies at UCB and UCLA, MORE enhances understanding by encouraging three key aspects of cognition in chemistry: (1) engaging in meta-cognition, (2) making connections between macroscopic observations and molecular-level mechanisms, and (3) refining personal models for consistency in light of experimental evidence.  Recently, we have adapted the MORE Thinking Frame for use in new instructional contexts, including general chemistry laboratory courses at a research university, a primarily undergraduate institution, a two-year college, and a high school.  This presentation will focus on diverse college students’ thinking and learning from a new introductory MORE module, “What happens when chemical compounds are added to water?”  Specifically, I will discuss the extent to which students engage in the three key aspects of cognition in chemistry as they participate in the laboratory module and relate this student thinking to molecular-level understandings displayed in interviews at the end of the semester.  I will also discuss the effects of context on students’ molecular-level ideas.

**Crossing cultural borders for Native American students in the earth sciences**
Eric Riggs Ph.D.
Co-Director, Center for Research and Engagement in Science and Mathematics Education
Purdue University, Dept. of Earth and Atmospheric Sciences, West Lafayette, Indiana

Native American reservation communities nationwide exercise sovereign control over natural resources and land-use within reservation boundaries. With the recent rapid economic growth of many of these communities, development pressures and infrastructure issues have become a foremost concern.  Despite the clear need for geoscience professionals on reservations and the deep cultural connection many American Indian cultures have with the Earth, Native American students remain very poorly represented in the earth sciences.  This has led to a lack of geoscientific expertise on reservations, which has led to understaffing of tribal environmental offices or staffing by non-natives without direct cultural and community ties. Reasons for low participation of Native Americans in the earth sciences are numerous, and can be linked to history, differences between Native and majority population worldviews, and teaching approaches and thinking styles common to many scientific fields.  The Indigenous Earth Sciences Project is an effort currently based at SDSU designed to address this problem systemically in Southern California and nationally by providing local, culturally-responsive avenues for success for college-bound American Indian students in the geosciences.  NSF GeoDiversity program funding has enabled us to begin to test our theoretical reasons for the success of field-based geoscience instruction in reaching Native learners, and to formalize programmatic elements and initiate collaborations with high schools serving reservations locally.  It has also allowed us to construct a school to work internship program in tribal environmental offices for Native high school and college students.  Further collaborations with Purdue University, Northern Arizona University, Bemidji State University and other institutions has allowed us also to begin to construct a national consortium of universities dedicated to furthering earth science education for indigenous communities. This presentation will outline the entire IESP program, strategies for replication and expansion elsewhere, and highlight research in cross-cultural science education of broad applicability that is resulting from this work.

**Implementing and evaluating instructional reform in the urban physics classroom**
Mel Sabella, Ph.D.
Department of Chemistry and Physics
Chicago State University, Chicago, IL

Physics Educators have developed a number of instructional environments to help students resolve robust conceptual difficulties.  Although many of these materials have been shown to be effective for many students, there is little research documenting improvements in conceptual understanding for students who attend school and live in an inner-city environment.  In many cases, we find that the needs and resources the students and teachers in these environments possess are quite different than those in other settings.

Because of this, the Physics Program at Chicago State University (CSU) is engaged in two curriculum development projects to address the needs of teachers and students in Chicago area high schools as well as the students in the introductory physics classes at a comprehensive urban institution.  In this talk I describe these programs and highlight some of the research documenting the effectiveness of our implementation.

Support for this project comes from a National Science Foundation CCLI grant – #0410068, the Illinois Board of Higher Education-Teacher Quality Enhancement Grant, and the American Physical Society-Physics on the Road Program (WYP 2005)

**Have you ever wondered…**
Joe Schwarcz Ph.D.
Director, McGill Office for Science and Society
Professor, Department of Chemistry
McGill University, Montreal, QC

Why for years and years there were no red M&M’s or how they get that maraschino cherry to float in the syrup inside a Cherry Blossom?  Why does popcorn pop?  Why are there holes in Swiss cheese?  Have you ever considered why there are no nuts or grapes in Grape Nuts Flakes or why witches supposedly use broomsticks as a method of transportation?  Why did Van Gogh mangle his ear?  Were Agatha Christie’s accounts of dastardly poisonings based on real science?  Can chocolate really make you fall in love?  After this presentation you’ll wonder no more!

**A middle school teacher’s perspective on standards based mathematics**
Meghan Southworth
Middle School Mathematics Teacher
Troy Howard Middle School, Belfast, ME 04915

There has been much talk about the use of standards based curricula in schools recently. In this presentation, we will take a look at my experiences in implementing some of these in a middle school setting,. We will also discuss the research-based foundation of some of these curricula.

**The role of “conceptual ecologies” in students’ science learning: Implications of the “warming trend” in conceptual change research**
Scott P. Sowell Ph.D.
Assistant Professor of Teacher Education
Cleveland State University, Cleveland, OH

The original conceptual change theory as outlined by Posner, Strike, Hewson, and Gertzog (1982) is an epistemologically grounded model of conceptual change based on a learner’s rational assessment of competing knowledge claims.  This theory provides a very purposeful means for educators to interact with their students’ prior knowledge about natural phenomena.  While these prior understandings do not often mirror accepted scientific explanations, they are very functional to the students themselves, holding strong explanatory power (thus, being rather resistant to change).  Hence, we value the conceptual change model for its ability to focus our attention on how well we orchestrate classroom experiences that promote students’ reflection on the need to modify existing conceptions.

A decade after the original conceptualization of the conceptual change model, two of the authors of this model, Strike and Posner (1992), suggested that the original model’s reliance on rational belief may “generate some blind spots” (p. 152), a critique that resonated and has been continued through the efforts of a host of other researchers as they worked to push past the rational, logical, strictly cognitive confines of this model.  The science education community’s response to this need to account theoretically for the role of affect, belief, and other extrarational factors in conceptual change has centered around expanding our understanding of the influence of the “conceptual ecology” on the change process.  In addition to presenting an overview of the current terrain of conceptual change research, as well as addressing overall implications of the model for science teaching/learning, we discuss our own research that uses the “conceptual ecology” construct to better understand preservice science teachers’ nature of science understandings

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A.  (1982).  “Accommodation of a scientific conception:  Toward a theory of conceptual change.”  Science Education, **66**, 211-227.

Strike, K. A., & Posner, G. J.  (1992).  “A revisionist theory of conceptual change.”   In R. A. Duschl and R. J. Hamilton, (Eds.), Philosophy of science, cognitive psychology, and educational theory and practice (pp. 147-176).  New York, NY:  State University of New York.

**Investigations of student understanding of thermal physics in the upper division**
John R. Thompson Ph.D.
Assistant Professor of Physics and Cooperating Assistant Professor of Education
University of Maine, Orono, ME

In research on the teaching and learning of upper-level thermal physics, we are probing student understanding of topics that are taught at the introductory level (e.g., work, heat, the first and second laws of thermodynamics, entropy) as well as more advanced topics (e.g., thermodynamic potentials, the Maxwell relations, chemical potential).  Many of our findings are consistent with prior work at the introductory level,1,2 however we find some differences for 2nd law topics.  Preliminary results suggest that upper-level undergraduates often enter a thermal physics course with little understanding of entropy, and emerge from the course with an ability to apply some features of entropy and the 2nd Law appropriately.  Difficulties with specific properties of entropy persist, especially with the state function property.  Another aspect of this research deals with student functional understanding of mathematical concepts applied in the context of thermal physics (e.g., path integrals, partial differentiation).  Our findings indicate that although students are able to take partial derivatives easily, many students have difficulty understanding the mathematical and/or physical significance of their differentiation, even after instruction.  I will discuss the development of an instructional approach to address specific difficulties found in our research.

1. M.E. Loverude, C.H. Kautz, and P.R.L. Heron, Am. J. Phys. **70**, 137 (2002).

2. D.E. Meltzer, Am. J. Phys. **72**, 1432 (2004).

Supported in part by NSF grant PHY-0406764.

**Improvement of student scientific reasoning skills: the effect of peer** **review** **and a lab report rubric**
Brianna Timmerman Ph.D.
Department of Biological Sciences
University of South Carolina, Columbia, SC

The ultimate achievement of science education is when our students successfully engage in real scientific investigations.   But real science does not end with the collection of data or production of a graph.  Peer review of science writing is the quality control mechanism for determining which scientists receive government funding and whose results are published in scholarly journals.  Not only are peer review and science writing two critical skills for real scientists, but they can also be used to accelerate student learning and scientific reasoning ability in the classroom.  In this talk I will present data on how the process of peer review has improved students¹ scientific reasoning abilities in a freshman biology class.  In addition, I have developed a universal rubric intended for use with science writing (especially lab reports) in any field of science (available at: http://www.biol.sc.edu/undergrad/curriculum.html) and will describe how the rubric has been used to as both an effective teaching tool and a useful assessment mechanism for tracking students¹ progress in developing scientific skills over time.   In particular, I will be presenting data on which scientific skills (e.g. hypothesis development, data analysis, etc.) seem to develop first in college freshman, which skills are easily mastered and which seem to remain challenging over time.

**Teaching, learning, and understanding trigonometric functions**
Keith Weber Ph.D.
Assistant Professor of Mathematics Education
Rutgers University, New Brunswick, NJ

Trigonometry is an important course in the high school mathematics curriculum. Understanding trigonometry is a pre-requisite for studying physics, engineering, and many branches of advanced mathematics. Further, as trigonometry is one of the first mathematics courses that integrates algebraic, diagrammatic, and symbolic reasoning, it can serve as a useful precursor for calculus.

In this presentation, I will argue that trigonometric operations, such as sine and cosine, can be understood in two different ways. These operations can be understood as ratios of the lengths of sides of right triangles. Alternatively, these operations can be understood as functions that map angles to real numbers. The goals of my presentation are to: argue that to fully understand trigonometry, one must understand trigonometric operations as ratios and functions present data from a research study illustrating that students in trigonometry courses taught in a traditional manner usually only understand trigonometric operations as ratios describe instruction that I have designed to enable students to understand these operations as functions present data illustrating that this instruction is effective

**Understanding the world using models of probability and probability density**
Michael C. Wittmann, Ph.D.
Assistant Professor of Physics and Cooperating Assistant Professor of Education
University of Maine, Orono, ME 04469

As part of a new course for non-science majors, Intuitive Quantum Physics, members of the University of Maine Physics Education Research Laboratory have created a series of activities for teaching probability and probability density. We use these activities to help students apply ideas from the everyday world to understand the probabilistic nature of quantum physics. We find that students have trouble learning the target concepts, such as using the ratio of time in a region to total time in all regions. Instead, they often: pattern match to previously studied situations, reason incorrectly about macroscopic elements of the system, use the gambler’s fallacy, and use ensemble results rather than expectation values to predict future events. We present data from pretests and examinations to show the progression of student understanding during instruction. We also show examples of instructional methods that help students develop the target ideas.

**Improving learning in an undergraduate science course: a case study of course re-design**
Richard Yuretich Ph.D.
Department of Geosciences
University of Massachusetts – Amherst, Amherst, MA 01003

Introductory courses have received most of the attention in efforts to improve the learning environment in college science courses, but upper-level courses also benefit from a focus on learning goals and the use of alternative teaching methods.  For a junior/senior geochemistry course I have successfully incorporated various methods of cooperative learning, including group analysis of questions or problems during class time, and long-term collaborative projects. Traditional exams have been replaced by frequent assignments, project reports, oral presentations and a reflective course summary.  Student feedback, achievement, and course evaluations indicate that students reach higher levels of learning and satisfaction that bode well for long-term retention of concepts. The data suggest that working collaboratively during class, discussing homework in class before the due date, and giving regular, timely feedback on assignments are the main reasons for the positive outcomes.

**Is the derivative a function? Natural language structures that enhance and hinder student understanding.**
Michelle Zandieh Ph.D.
Associate Professor of Mathematics and Statistics
Arizona State University, Tempe, AZ

Is the derivative a function?  This is a trick question, as we can plainly see from one AP calculus student’s response.

**Ingrid:** It’s just a slope. It’s like — [short pause] It’s not like y equals something. If you just have a derivative, the derivative is — I guess you could say — I just keep thinking, cause you can’t graph just a slope.

**Researcher:** Just a slope?

**Ingrid:** Or you can’t graph a limit. But then if you say like what’s the derivative. Like on a test, ‘this is the graph of the derivative.’ I guess it has to be. It could be a function.

In normal mathematical dialogue we say “derivative” both when we refer to a function and we refer to a value of that function at a certain point.  It is very common in natural language to have words that have more than one meaning but whose meanings are closely linked in some way.  In mathematics, however, we typically expect that terms are defined and that once defined, the only alternative definitions allowed are those that are equivalent to the original definition.  Thus the interplay between natural language usage of words and mathematical language usage is complicated and the results may aid or obstruct students’ reasoning.  In this talk I will use examples from interviews with AP calculus students to illustrate both powerful and problematic use of language for students in their understanding of the concept of derivative in calculus.  In particular, I will outline a structured framework for describing what the mathematics community means by understanding the concept of derivative at the level of beginning calculus and show how the natural language construct of metonymy (defined in the talk) and metaphor are both imperative to student understanding of the key connections involved in understanding derivative but also are the source of several key misstatements that students make when discussing the derivative.