TRUSE 2017
Plenary Speakers, Titles, Abstracts

Sandra Laursen, University of Colorado – Boulder, Chemistry

All ER is not DB: Optical properties of the disciplinary lens

Taking on my designated mantle as a "cross-disciplinary" speaker, I will reflect on when it may be useful for DBER scholars to wear their disciplinary lens, and when it may be a hindrance. I will discuss two ongoing studies where putting on or taking off the disciplinary lens has been important. At the very least, researchers should learn to recognize when we are wearing this lens and learn to remove it or to apply corrective optics when needed.

Leslie Atkins Elliott, Boise State University, Physics

Title: Teaching for Transfer in Science: Making Ideas Accountable to Students' Lives

This talk builds on recent research in transfer, with particular interest in transfer that is captured by the construct of "transformative experience" (TE): those moments in which students spontaneously choose to use science ideas in their everyday lives, rather than solely in later classroom contexts. In particular, I examine episodes of intercontextuality that exist in a science class that exhibits high measures of TE. I argue that moments when students' developing scientific ideas are held accountable to out-of-class contexts may be particularly rich for fostering TE in particular, and transfer more generally.

Luanna Prevost, University of South Florida, Biology

Automated approaches for assessing student writing.

Formative written assessment provides researchers, educators and students themselves with insight into student thinking during the learning process. However, written assessments have limited use in large enrollment undergraduate STEM courses due to the time and resources required to grade and provide feedback. Automated scoring approaches can overcome these barriers by modeling human scoring using text analysis, machine learning and classification techniques. These approaches identify and extract words and phrases from student writing, and build scoring models. Models predict human scoring from analytic or holistic rubrics and are tested with new datasets until high human-computer agreement is achieved (>0.7 Kappa). Finally, models are implemented in the classrooms of instructors participating in faculty learning communities at six different institutions. The reports generated from these scoring models are used to drive reflection on teaching and have led to the development of new instructional activities.

Daniel Rienholz, San Diego State University, Mathematics

Systemic change in STEM departments: The four frames model

Decades of research highlight ways to improve teaching and learning in undergraduate STEM classrooms. However, there are many challenges associated with achieving broad implementation and sustainability of these new forms of education. In other words, a recent challenge is not just studying how to improve teaching and learning but increasing the uptake of already known improved forms of teaching and learning. To address this challenge, scholars have begun applying theories from organizational learning to better understand how to launch successful change efforts in STEM departments. In this talk, I describe an adaptation of one such model from organizational theory: the four frames model. I offer an overall theoretical introduction as well as practical guidance for implementing and sustaining change.

Erin Dolan, University of Georgia, Biology

When Undergraduate Research Becomes the Curriculum

National calls to improve undergraduate STEM education have emphasized the importance of undergraduate research experiences. Course-based Undergraduate Research Experiences, or CUREs, involve groups of students in addressing research problems or questions in the context of a class, and have been proposed as scalable ways of involving undergraduates in research. This session will offer a definition of CUREs, describe what makes them distinctive from other learning experiences, outline the state of knowledge about CURE effectiveness, and highlight results from a study of the Freshman Research Initiative as a unique and highly impactful CURE model.

David Kung, St. Mary's College of Maryland, Mathematics

The Roles of Pedagogy and Educational Research in Diversifying STEM Fields

Women and under-represented minorities are more likely to fall out of the STEM pipeline at every stage from middle school on. What can we do in our classrooms, departments, and institutions to ensure that everyone has an opportunity to succeed? Research suggests that interactive teaching methods, in contrast to passive lectures, might help us successfully address issues of diversity. Why do they work? What research questions should we be asking to help move the needle in the right direction?

Natasha Speer, University of Maine, Mathematics

College instructors at work: Mathematical knowledge for teaching calculus and the practice of examining student work

In addition to being prepared as research mathematicians, graduate students develop their teaching practices while in their doctoral programs. Although many departments now provide teaching-focused professional development, questions remain about how to help graduate students develop the knowledge and practices needed to implement active and inquiry-based approaches to instruction. Such practices rely on rich knowledge of how students think and the capacity to interpret new things that students say and do. College mathematics instructors also use and, importantly, *develop* such knowledge when examining students' written work on tests and homework. In this session, we will examine knowledge used and developed by college mathematics instructors as they examined students' answers to calculus questions. Implications for the design of instructor professional development for on-the-job learning will also be discussed.

Michelene T. H. Chi, Mary Lou Fulton Teachers College Arizona State University

"ICAP: How to Promote Deeper Active Learning Engagement"

ICAP is a domain-general and parsimonious theory that takes the perspective of the learners, and defines four different ways or modes that students can engage with instruction or instructional materials, often referred to as "active learning." These four ways of engaging can be approximated by students' overt behaviors and the products they produce, based on what students are asked to do. These four different modes are: Interactive or collaborative, Constructive or generative, Active or manipulative, and Passive or attentive. Based on plausible knowledge-change processes corresponding to each mode of behavior, ICAP predicts that learning is best in the Interactive mode, followed next by the Constructive mode, then the Active mode, with the Passive mode fostering the least learning. That is, relative to each other, each mode of engagement achieves a different level of learning, in the hierarchical order I>C>A>P. This hypothesis suggests that the two highest modes, Interactive and Constructive, foster the deepest learning. The ICAP hypothesis can explain the results of hundreds of laboratory and classroom studies in the literature. It also provides operational definition for what activities correspond to each mode. I will discuss common instructional techniques that others have used, and predict which ones will be more enhancing for deeper learning.

Megan Wawro, Virginia Tech, Mathematics

Student Understanding at the Intersection of Linear Algebra and Quantum Physics

The NRC's (2012) *DBER Report* called for additional research that investigates student understanding of cross cutting concepts in undergraduate STEM courses, which could inform increased coherence in students' learning experience across STEM disciplines. With *An Interdisciplinary Study of Learning: Student Understanding of Linear Algebra in Physics*(*Project LinAl-P*), I aim to contribute towards this need by investigating students' reasoning about and use of mathematics in physics. More specifically, the focus of *Project LinAl-P* is students' understanding, symbolization, and interpretation of eigentheory and related ideas from linear algebra in quantum mechanics. In my talk, I will share results from two ongoing research threads of *Project LinAl-P*. One thread involves analysis regarding students' meta-representational competence (MRC) that is expressed during semi-structured individual interviews as students solve quantum mechanics problems that involve eigentheory. 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, to judge their suitability for various tasks (diSessa, 2004). I will share examples from the data and explore the relationship between strong MRC and a student's understanding and symbolization of eigentheory in quantum mechanics. The second research thread investigates student reasoning about linear combinations of eigenvectors. Using written data from over 100 linear algebra or physics students, I will share preliminary analyses regarding why this may be a particularly challenging aspect of the eigenspace concept and what ways of reasoning may be particularly powerful for developing a conceptual understanding of eigenspaces.

Nicole Becker, University of Iowa, Chemistry

Undergraduate chemistry students' conceptualization of models in the general chemistry sequence

Many undergraduate chemistry students approach mathematical problem solving algorithmically and struggle to connect mathematical equations to the macroscopic and particulate-level phenomena they represent. Additionally, despite working with various types of models in the introductory chemistry sequence, students may fail to develop robust epistemological understandings about the role mathematical and other models play in scientific inquiry. Here, we discuss findings from research into students' reasoning about mathematical models in chemistry contexts and discuss routes towards promoting more meaningful engagement in model-based reasoning and mathematical thinking in the general chemistry sequence.

Danny Caballero, Michigan State University, Physics

Researching Computing in Physics Education at a Variety of Scales

Computing has revolutionized how modern science is done. Scientists use computational techniques to reduce mountains of data, to simulate impossible experiments, and to develop intuition about the behavior of complex systems. Much of modern STEM work would be impossible without the use of computing. And yet, while computing is a crucial tool of practicing scientists, most modern science curricula do not reflect its importance and utility. In this talk, I will discuss the urgent need to construct curricula in physics that integrates computing and the research that begins to investigate the challenges of doing so at a variety of all scales -- from the largest (institutional structures) to the smallest (student understanding of a concept). I will provide several examples of research with students, focused on a variety of topics, that leverage quantitative and qualitative approaches. This presentation is intended as a conversation about how this research has evolved over the last few years and aims to illustrate the benefits and shortcomings of that work. Research at the intersection of computing and physics requires new foundational, applied, and experimental work. While the research I will present occurs in physics, there are implications for the other STEM fields as computational science, data science, and other technology-enabled quantitative approaches to science and engineering grow across STEM.

Sam Pazicni, University of New Hampshire, Chemistry

Title: Of comprehension and text: Studies of language and learning chemistry

While mathematical ability has long been implicated as crucial for learning chemistry, language ability remains largely uninvestigated. This contribution explores correlations between language comprehension and performance in general chemistry, as well as how general chemistry students interact with text-based learning materials. Structure Building, a model that describes how linguistic information is incorporated into one's existing knowledge base, guides our work. We demonstrate that comprehension ability correlates strongly with chemistry course performance. An examination of variables predicted to interact by the Structure Building Framework suggests that high comprehension ability may be sufficient to compensate for low prior knowledge. Intriguingly, our results also suggest that instruments used to measure comprehension ability and math ability are not wholly independent of one another. We also report the design and analysis of a multiple-testing intervention strategy that differentially aids those of low comprehension ability. The effect of question type (multiple choice versus elaborative interrogation) on this multiple-quizzing strategy has also been investigated. With regard to text-based learning materials, we carried out linguistic analyses of popular general chemistry texts, the results of which suggest that these materials are appropriate for only low-knowledge students. Further studies probing the extent to which students benefit from reading texts on chemical bonding and redox concepts revealed an expertise reversal effect, corroborating these textual analyses.

Tessa Andrews, University of Georgia, Biology & Marilyne Stains, University of Nebraska – Lincoln, Chemistry

The complexity of instructional change: Considering external and internal drivers

Despite abundant evidence that traditional approaches to undergraduate STEM education are insufficient and multiple prominent calls for reform, many instructors continue to teach primarily by lecturing. This suggests that the most pressing challenge in STEM education reform is facilitating change, rather than developing or refining evidence-based instructional practices. Faculty commonly cite lack of time, incentive, and expertise as barriers to adopting these practices, but interventions designed to mitigate these barriers have been insufficient. There is growing recognition that instructional change is complex and likely requires fundamental changes in context and individuals. However, lack of understanding of the external and internal drivers of decisions instructors make about changing their teaching is hindering our ability to promote widespread reform. In this talk, we will describe an investigation that aims to elucidate the differential impact of factors influencing teaching practices. This work provides an empirically tested model of instructional change that can inform future reform efforts. We will also present an in-depth study of the impact of colleague-colleague interactions and department practices on teaching decisions. This work identifies people and practices who are particularly influential and could be leveraged to promote change locally. Finally, we will highlight a study of a previously uninvestigated factor that may affect instructional change, professional identity. This study investigated professional identity among doctoral students and what influences identity development. It provides insight into how doctoral training could be reconsidered to produce future faculty who see themselves as researchers *and* teachers and are primed to engage in evidence-based teaching.

Unpacking evidence-based instructional practices: What does it take to be effective?

The research and development of evidence-based instructional practices (EBIP) has been on-going for decades in discipline-based education research. Although the impact of these practices on student outcomes has been studied extensively, the inner workings of EBIP have been largely uncharacterized. Not knowing why, how, and under what conditions EBIP produce desirable outcomes severely impairs their effective propagation and the quality of their implementation by STEM instructors. Moreover, most investigations on the effectiveness of EBIP do not measure and take into account the extent to which the practice was implemented as intended by the developers. This lack of attention to the fidelity of implementation of EBIP in the characterization of their impact compromises the validity and reliability of claimed student outcomes. In this talk, we will describe a methodological framework that enables the characterization and measurement of the inner workings of EBIP. In particular, we leveraged the extensive literature on fidelity of implementation from other disciplines to develop a framework to measure fidelity of implementation in an educational setting. We will also highlight a study that illustrates how critical elements to the implementation of EBIP can be unpacked. This work focuses on instructor knowledge critical for effective implementation of EBIP. Finally, we will share the development of a method to measure critical elements of a particular EBIP.