

# RESEARCH SCHOLARSHIP 2012 2013

## TACKLE the BIG QUESTIONS

without as understood

How does community  
in the learning  
environment impact  
learning?  
Melissa M. Brown

HOW CAN WE  
HELP STUDENTS  
GAIN INFORMAL  
EXPERIENCES THAT  
CHANGE AND ENHANCE  
STUDENTS' PERSONAL  
LEARNING  
EXPERIENCES?  
PK

HOW MUCH OF THE BEHAVIOR WE  
OBSERVE IN ENGINEERING STUDENTS  
IS BECAUSE STUDENTS ARE NONDIVERSITY  
DIVERSE? HOW MUCH IS INFLUENCED  
BY THE UNIVERSITY, BY ENGINEERING,  
AND BY THE DEPARTMENT?  
MATTHEW CINCARD

Why are some concepts  
so difficult to learn?  
Kara Sorensen

How do  
people know  
they have learned  
(to be engineers,  
designers, interdisciplinary  
change agents, etc.)?  
MWA & client

How does workplace  
engineering translate  
and contribute to  
engineering education  
at all levels?  
J.P. S. Brown

What do engineers know  
and where do they learn it?  
David Radcliffe

HOW CAN WE IMPROVE THE ABILITY OF  
ENGINEERS TO WORK IN GLOBAL CONTEXTS?  
-BRENT K. JESSEK

Why don't engineering faculty embrace  
research and evidence based practices in  
teaching and learning?  
Kara Smith

How can we  
prepare  
the teachers  
of tomorrow  
while  
addressing  
human social  
community needs  
of today?  
Muller  
Della

How do we best prepare engineers for their role  
in society?  
K.H.





+ Purdue's pioneering School of Engineering Education is a vibrant community of scholars who are radically rethinking the boundaries of engineering and re-imagining engineering education, in the broadest sense, to meet the challenges of the future. We seek to transform engineering education based on research and scholarship. This transformation begins when we challenge the unstated assumptions underpinning traditional engineering education: that "business as usual" will get us to where we need to be.

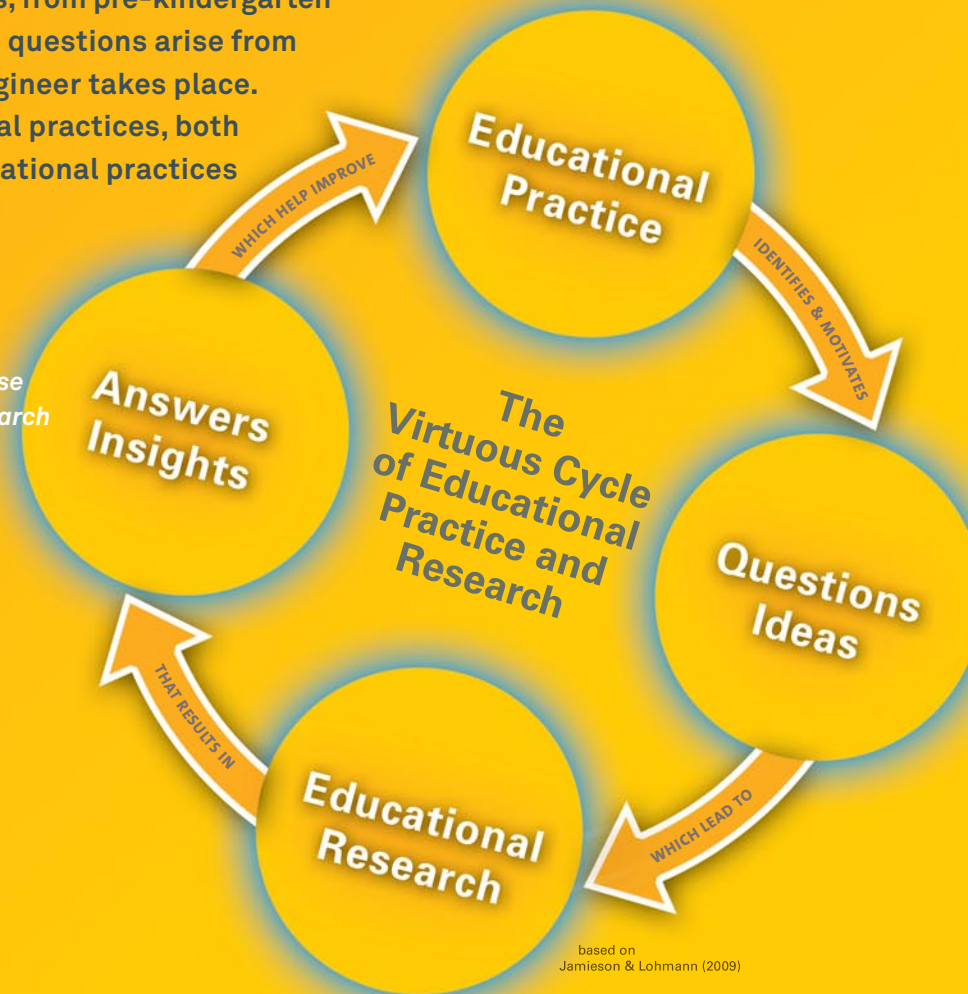
Our research is about understanding knowledge construction and sharing and community membership processes in relation to engineering across all life stages, from pre-kindergarten through the college years and over a career. The motivating research questions arise from diverse settings, where learning about engineering or learning to engineer takes place. In turn, our research findings are helping shape improved educational practices, both formal and informal. Thus educational research and innovative educational practices form a virtuous, interdependent cycle.

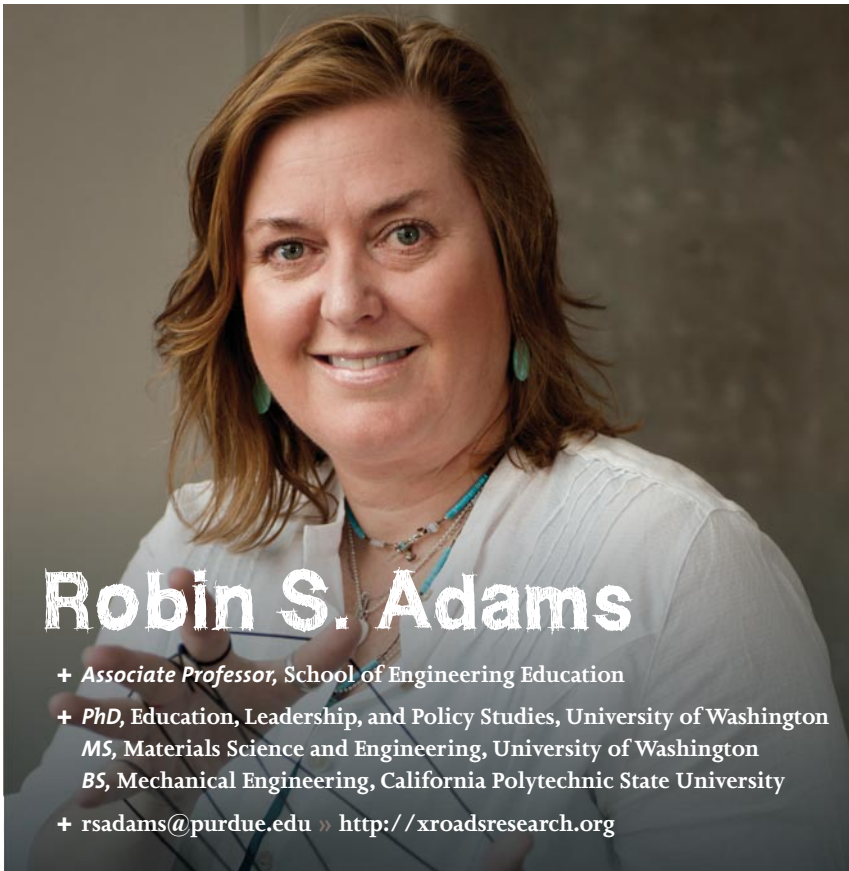
*I invite you to explore the diverse scholarly interests of our faculty members. They are passionate, imaginative individuals driven by curiosity and a shared sense of mission. Many are thought leaders in their specialty, and collectively their research has had a significant influence on the national and global dialogue on reforming engineering education. I hope you find something that piques your interest.*



A handwritten signature in black ink, appearing to read "D Radcliffe".

David F. Radcliffe  
Kamyar Haghghi Head,  
School of Engineering Education  
Epistemology Professor of  
Engineering Education





## Robin S. Adams

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*The recipient of a 2008 NSF CAREER Award, a Design Studies best paper award (2003), and the Journal of Engineering Education's Wickenden Award for best paper (2008), Dr. Robin S. Adams is a leader in researching cross-disciplinary and design thinking and learning, synergizing research and practice, building research capacity in engineering education, and enabling educational transformation. She designed and led the Institute for Scholarship on Engineering Education as part of the Center for the Advancement of Engineering Education and was an invited participant at the National Academy of Engineering's 2010 Frontiers of Engineering Education symposium.*

**How do you know you've learned?** |→ Answering this question requires a “language of learning”—a way of talking about what it means to know, be able to do, or be as a professional—and an understanding of how and why this changes over time and through experiences as a learning trajectory. A language of learning helps learners self-assess their own progress, educators design and assess learning experiences, and leaders take action and shape the future of engineering education and engineering as a profession. Dr. Adams' research seeks to empirically develop languages for learning in areas central to the practice of engineering—cross-disciplinary and design—and the practice of engineering education. Her group, XRoads, conducts research at the “crossroads” where different perspectives connect, collide, and catalyze new ways of thinking.

**Cross-disciplinary ways of thinking, acting, and being** |→ Every day, engineers are confronted with complex and ill-structured challenges that cannot be addressed through a single lens or mindset. Grand “human” challenges require “cross-disciplinary” approaches for thinking, working, and innovating across differences (cultures, disciplines, and lived experiences). While multi-, inter-, and even transdisciplinarity are widely endorsed as critical engineering education goals, our understanding of a language of cross-disciplinary learning is very limited. What is it you learn? How? How would you know if you learned or could apply what you learned to new situations? How does this become a part of who you are and how you approach complex human-social-technical-environmental problems?

Dr. Adams' research seeks to build theories about learning and becoming “cross-disciplinary” in multiple contexts: engineering, design, cancer research (epigenomics), and engineering education. Her CAREER grant, a three-year longitudinal study, investigates how and why people become effective cross-disciplinary practitioners, drawing on critical incident, photo elicitation, and narrative methods to make visible what undergraduates, graduates, faculty and practicing engineers come to understand through their cross-disciplinary experiences. Dr. Adams has developed frameworks of cross-disciplinary learning (see figure), tools to assess cross-disciplinary problem formulation and collaboration capabilities, and novel methods for investigating how and what people learn through their experiences, and she is collaborating with faculty to form a “Cross-disciplinary Commons”

to share approaches to cross-disciplinary teaching, learn from each other, and transfer new ideas for use in their own classrooms.

### Engineering design learning trajectories and education for innovation

↳ Dr. Adams has conducted in-depth studies of how freshman and senior engineers compare to practicing professional engineers that illustrate critical differences in the use of iterative design strategies, breadth and depth in framing and understanding the problem, and awareness of ambiguity and uncertainty. She integrates this work with research in diverse disciplines (such as engineering, architecture, product design, visual and performing arts, and computer science) to help create a language of design learning that characterizes learning progressions in what designers know, what they are able to do, and how they see themselves as design professionals. This research has been used to guide approaches to design curriculum (from P-12 to postgraduate as well as within and across disciplines) and professional development of design educators, to develop tools to measure changes in design learning over time, and to create the graduate-level course “Design Cognition and Learning.”

### How does engineering education transformation happen?

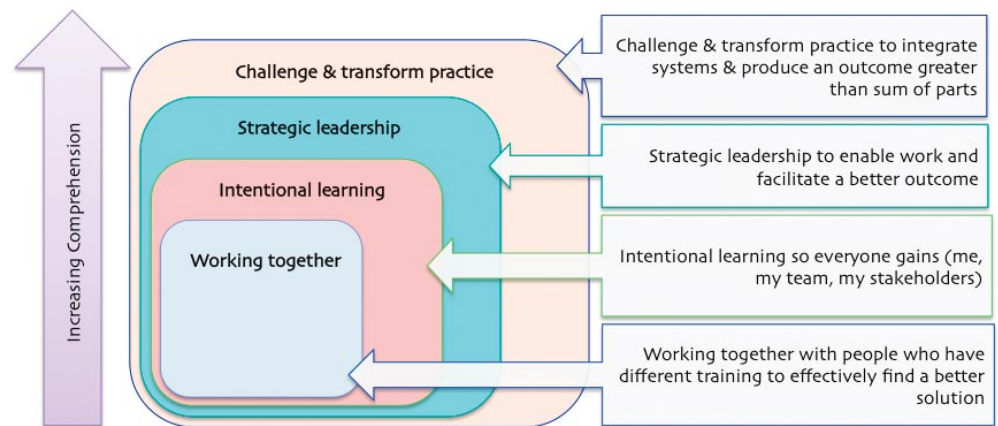
↳ Drawing on cross-disciplinary and complex-systems methods, Dr. Adams seeks to both catalyze change and understand the process of engineering education transformation. She has developed novel ways to bring research “into the classroom,” such as using storytelling with engineering educators to build communities of practice and translating tools used for research into educational strategies that help learners talk about learning in ways that support reflective practice and identity development. She also uses multiple-perspective methodologies to critique and open up new ways of thinking about the aims and process of engineering education. In the course “History and Philosophy of Engineering Education,” she draws on philosophy and history to chal-

lenge and transform ways of thinking about engineering knowing and what it means to prepare engineers for the profession. Dr. Adams also uses her “language of learning” lens to study the process of engineering education transformation. She draws from multiple perspectives to investigate how engineering educators link their own work as researchers to their work as educators, how engineering faculty experience shifts in thinking around curriculum design, and how successful “changemakers” understand and talk about the process of educational transformation (their “change knowledge”) and themselves as change agents.

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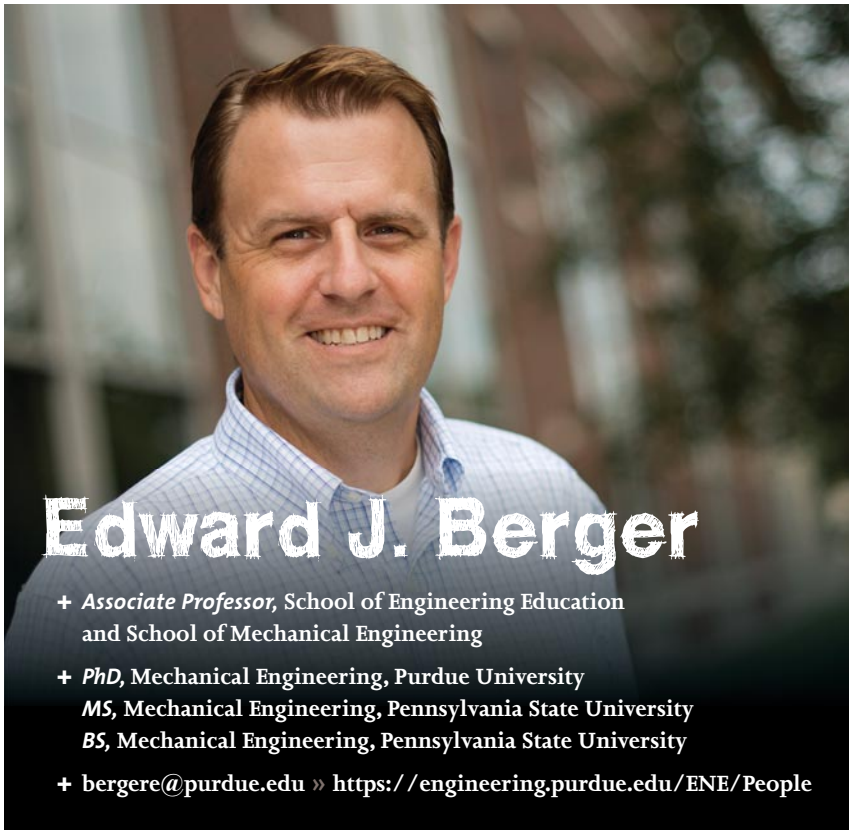
[FUNDING] NSF DIVISIONS OF UNDERGRADUATE EDUCATION AND OF ENGINEERING EDUCATION AND CENTERS; NATIONAL INSTITUTES OF HEALTH

A Progression From Surface to Deep Awareness of Cross-Disciplinary Ways of Thinking, Acting, and Being



**KEY PUBLICATIONS** Adams, R.S., Turns, J. & Atman, C.J. (2003). Educating effective engineering designers: The role of reflective practice. *Design Studies*, 24(3), 275-294. [Design Studies best paper]. Adams, R.S., Daly, S., Mann, L.L. & Dall’Alba, G. (2011). Being a professional: Three lenses on design thinking, acting, and being. *Design Studies*, 32, 598-607. Adams, R.S., Dias de Figueiredo, A., Evangelou, D., English, L.D., Mousoulides, N., Pawley, A., Schifellite, C., Stevens, R., Svinicki, M., Trenor, J. & Wilson, D. (2011). Multiple perspectives on engaging future engineers. *Journal of Engineering Education, Centennial Issue*, 100(1), 48-88.





## Edward J. Berger

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*With research and teaching experiences in the mechanical, biomedical and civil engineering disciplines, Dr. Edward J. Berger is well suited for the demands of engineering education research. He believes that in order to make a difference in the quality of teaching and learning, one needs to consider the research basis for engineering education approaches, as well as research in difficult disciplinary problems. Dr. Berger examines the use of social media for effective teaching and the emerging institutional research area of predictive models for student academic success. Prior to his appointment at Purdue, Dr. Berger served as the Associate Dean for Undergraduate Programs in the School of Engineering at the University of Virginia.*

**Teaching with technology** |→ Using new media to teach engineering and assessing its impact are two areas of research for Dr. Berger. Bringing social media into the classroom, he has examined how it is used as a teaching tool in the hands of instructors and among students. The research employs social constructivism, cognitive load theory and active learning techniques, among other methods, to understand the impact of technology on student learning outcomes. Future research will focus on student-generated content—a subject that has received little attention.

The use of video technology in teaching has created additional areas of study. Dr. Berger is researching how to best organize, catalog and distribute content so that students are empowered to access it efficiently. A possible solution is the *Engineering Genome Project*. He hopes the organizational structure will make the hundreds of video files accessible to students.

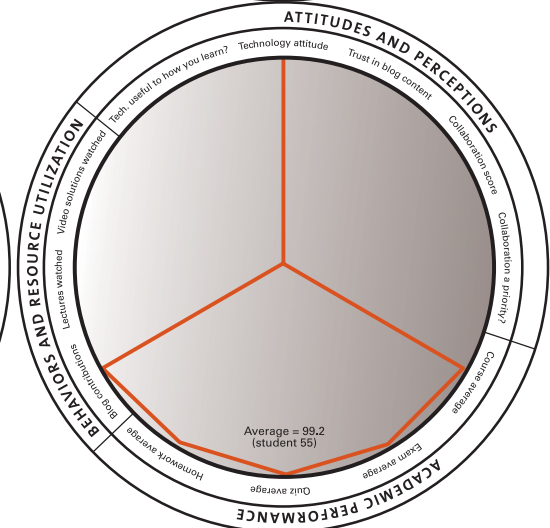
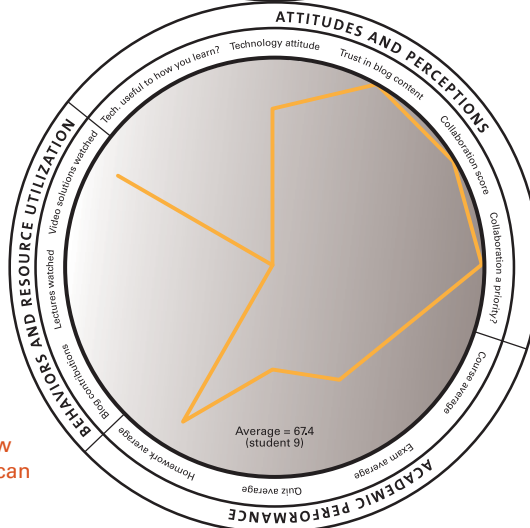
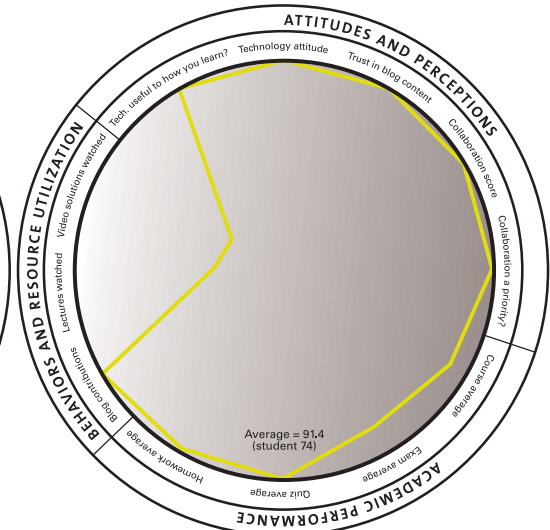
**Predicting undergraduate engineering outcomes** |→ Engineering programs attract many high-achieving students with strong academic backgrounds. So why do some seemingly strong students, with strong academic pedigrees, struggle and even fail when they enter the university? Dr. Berger's research focuses on the underlying questions of why some “strong” students fail. He believes non-cognitive skills need closer examination. Those include grit, self-control, open-mindedness and optimism. He hopes to understand why previously high-achieving students stumble and sometimes fail in a university setting, and to intervene before they face such a situation.

**Discipline-based engineering education research** |→ How does a student gain disciplinary knowledge so that he or she goes from novice to expert? Dr. Berger is researching the challenges of gaining expertise in complex engineering disciplines. He believes the greater his discipline-specific research, the greater his abilities to teach the subject and his abilities to research those teaching methods. Turning the “microscope” on this interdependent relationship and finding ways to improve each part results in continuous improvement of disciplinary expertise and teaching effectiveness.

[FUNDING] NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY;  
NSF DIVISION OF UNDERGRADUATE EDUCATION

“Engineering education research fits into a cyclic and symbiotic relationship with both my teaching and technical, disciplinary research. I feel very strongly that in order to make a discrete difference in the quality of teaching and learning at my institution, I need to be thinking about the research basis for engineering education approaches, as well as research in difficult disciplinary problems.”

Students' attitudes about collaboration and technology, their usage of technology for learning, and their course performance can show complicated relationships. These radar plots illustrate how students with very different attitudes and consumption patterns can nonetheless achieve equivalent academic performance.



**KEY PUBLICATIONS** Orange, A., Heinecke, W., Berger, E., Krousgrill, C., Mikic, B., and Quinn, D., “An Evaluation of HigherEd 2.0 Technologies in Undergraduate Mechanical Engineering Courses”, *Advances in Engineering Education (ASEE)*, Vol. 3, No. 1, Winter 2012. Berger, E. J. and Krousgrill, C. M., “HigherEd 2.0: Web 2.0 in Higher Education”, in *Interactive Multimedia* (ed. I. Deliyannis), INTECH, pp. 67-92, 2012 (book chapter).



## Sean P. Brophy

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*Dr. Sean P. Brophy's expertise in systems engineering and educational research fuels his work on systems thinking and knowledge transfer used in his designs of effective learning environments and cognitive devices. A recipient of the *Journal of Engineering Education's* Wickenden Award for best paper (2007) and an invited participant at the National Academy of Engineering's 2010 Frontiers of Engineering Education symposium, he has helped lay the foundation for a new paradigm—challenge-based instruction—in engineering education.*

**Thinking about complex systems** |→ Engineering students think with models of systems to comprehend and solve complex problems. Dr. Brophy's research explores how students approach the initial stages of design and problem-solving activities: comprehending a situation and defining the fundamental problem. This work is helping to identify how students generate diagrams and graphs they can use to explain how a device or system works. By posing “what if” questions to these students, his team has learned how well they can use their representations to explain and predict the systems' performance in various scenarios. Dr. Brophy has been awarded an NSF grant (“Graphical Representations to Assess System Performance,” or GRASP) to explore these fundamental skills and to design a formative assessment system to help students develop this ability to reason with models.

**Transferring knowledge to new contexts** |→ Engineers can adapt to novel problem-solving conditions because they have a rich conceptual model that supports their generation of knowledge in unfamiliar contexts. Dr. Brophy leverages his mechanical engineering background to research how learners—including elementary-age, middle-school, and undergraduate students—develop a rich conceptual understanding of physical concepts (e.g., force, conservation of energy) that govern how a system behaves.

As a computer scientist, Dr. Brophy has designed devices that help students learn while maximizing their potential to successfully transfer newly learned knowledge to new problem-solving situations. For example, he has collaborated with Dr. Alejandro Strahan, a domain expert in Purdue's Network for Computational Nanotechnologies (NCN), to identify learning gains with visualizations of how materials behave at the atomic level when external forces are applied at the macro level. Students used a computational model on nanoHUB.org to dynamically generate images of material structures at the atomic scale. The experiment demonstrated students' ability to transfer knowledge learned in a virtual lab to a novel problem presented on a post-test. Dr. Brophy is integrating these ideas into new projects for the Network of Earthquake Engineering Simulation (NEES), as well as for WaterHUB (for cyber-enabled training, education, and research related to hydrology).

**Designing effective learning environments** |→ Challenge-based learning environments provide advanced learning experiences critical to the future of engineering education. Dr. Brophy’s published research demonstrates how problems presented in an authentic context help learners acquire knowledge they can transfer into novel situations. Through this work he has been able to contribute to the growing knowledge of methods for designing effective learning environments based on theories of learning and the “How People Learn” framework. Dr. Brophy is working on methods to make the design of learning environments as accessible to other faculty as designing traditional lecture-style courses.

Dr. Brophy continues to develop and research advanced models of problem-based learning with cyber-enabled technologies. Cyber-tools like GRASP and simulation tools engage students in intellectual tasks to better comprehend and evaluate how systems behave. Further, technologies can support team members’ interactions with each other to enhance the productivity of the team. For example, Drs. Brophy and Daniel DeLaurentis received funding to design

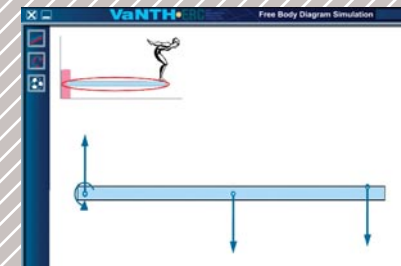
a challenge-based learning environment for aerospace design using an interactive 3D world. This project has great potential to achieve multiple learning objectives, including knowing conditions for applying content knowledge, developing team design skills, and learning what it means to work as a professional in an engineering context. These same ideas inform the design of a new cyber-learning space called NEESacademy to support the education and outreach needs of the Network for Earthquake Engineering Simulation (NEES), a cooperative agreement with the National Science Foundation.

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**[FUNDING]** NSF DIVISIONS OF UNDERGRADUATE EDUCATION; OF ENGINEERING EDUCATION AND CENTERS; OF CIVIL, MECHANICAL, AND MANUFACTURING INNOVATION; AND OF RESEARCH EXPERIENCES FOR UNDERGRADUATES

Dr. Brophy explores learners’ use of conceptual models to build, explain, and analyze systems.

(below) Progressive models of understanding force, for use by preschoolers, elementary-age students, and undergraduates.

## How do engineering students think with models to make sense of systems?



**KEY PUBLICATIONS** Brophy, S., Klein, S., Portsmore, M. & Rogers, C. (2008). Advancing engineering in P-12 classrooms. *Journal of Engineering Education*, 97(3), 369–387. Roselli, R.J. & Brophy, S.P. (2006). Effectiveness of challenge-based instruction in biomechanics. *Journal of Engineering Education*, 95(4), 311-324 [JEE Wickenden Award]. Brophy, S., Magana, A. & Strahan, A. (in press). Lectures and simulation laboratories to improve learners’ conceptual understanding. *Advances in Engineering Education*.





## Monica E. Cardella

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*Recipient of a 2011 NSF CAREER Award and the Journal of Engineering Education's Wickenden Award for best paper (2008), Dr. Monica E. Cardella conducts research in how children develop engineering thinking skills in informal learning environments, focusing primarily on engineering design and engineering mathematics. She also investigates the development of mathematical thinking and design skills at the undergraduate level.*

**Understanding the relationship between design and mathematics** |→ In work that can inform both undergraduate engineering education as well as the national discussion on mathematics at the K-12 level, Dr. Cardella's CAREER Award-funded research explores the interplay between mathematical thinking and design thinking—specifically, how undergraduate engineering students' learning experiences in required mathematics courses impact how they learn engineering design. This is particularly important because design is closely tied to innovation.

Using verbal protocol analysis, which has been employed successfully in past studies to understand design thinking, Dr. Cardella investigates students' thinking as they work on an engineering design challenge. Students are asked to "think aloud" while working on the challenge, and video recordings of the "think alouds" are examined to determine the types of mathematical thinking activities the students engage in (e.g., how they use mathematical content knowledge, how they employ mathematical problem-solving strategies and mathematical practices like estimation or the use of numerical evidence to form an argument), as well as the design thinking activities the students engage in.

In the data collected for her CAREER-funded project as well as for previous studies of teams of engineering students and practitioners, Dr. Cardella looks for patterns in terms of the types of strategies students use, the point in the process when they begin to use a form of mathematical thinking (such as mathematical content knowledge, mathematical problem-solving practices, mathematical resources, or mathematical practices such as estimation or a mathematical form of argumentation) or when or if they become "fixated" on one design solution and don't consider other options.

Ultimately, this research provides a foundation for future research related to design and mathematical thinking as well as more-immediate outcomes such as improvements in the teaching of engineering design and mathematical modeling in Purdue's First-Year Engineering Program.

**Informal learning environments** |→ Traditionally, educational research in general and engineering educational research in particular have focused on students’ experiences with learning engineering within curricular structures. However, as students spend the majority of their time in out-of-school settings, it is important (and fruitful) to understand the learning that occurs outside the classroom. This is particularly true for pre-college students, many of whom receive either limited or no engineering instruction in their K-12 classes.

Dr. Cardella has developed key research partnerships with the Science Museum of Minnesota and WGBH (the Boston-based television studio) to investigate how children learn about engineering through play dates with their parents, museum exhibits, television shows, and web resources. As the director of INSPIRE’s newly formed Informal Learning Environments Research team, she mentors a team of graduate students engaged in research on engineering learning in other contexts, such as through storybooks or through other family interactions. This research on understanding the engineering learning that occurs in informal environments provides a foundation for research-informed design of learning experiences for K-12 classrooms, facilitating opportunities for all children to learn about engineering.

**Assessment instruments for measuring engineering thinking** |→ There is a need for valid, reliable assessment instruments within the pre-college engineering education research community for measuring engineering thinking. Dr. Cardella has developed research-tested instruments including modified versions of Bailey’s “Design Process Knowledge Task” (measuring elementary students’ and teachers’ understanding of the engineering design process), the “Human-Centered Design Task” (measuring undergraduates’ understanding of human-centered design), and the “Parent Engineering Awareness Survey” (measuring the knowledge, attitudes, and behaviors of parents

of K-12 students in respect to engineering and engineering education). She has also studied the effectiveness of different measurement practices.

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[FUNDING] NSF DIVISIONS OF ENGINEERING EDUCATION AND CENTERS, OF HUMAN RESOURCE DEVELOPMENT, AND OF RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS; THE S.D. BECHTEL JR. FOUNDATION; INSPIRE

Research into how children develop engineering thinking skills in informal environments (like the Children’s Museum of Indianapolis, below) can lead to better learning experiences in K-12 classrooms.



**KEY PUBLICATIONS** Atman, C.J., Adams, R.S., Cardella, M.E., Turns, J., Mosborg, S. & Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. *Journal of Engineering Education*, 96(4), 359-379 [JEE Wickenden Award]. Cardella, M.E. (2008). Which mathematics should we teach engineering students? An empirically-grounded case for mathematical thinking. *Teaching Mathematics and its Applications* 27(3), 150-159. Hsu, M., Cardella, M.E. & Purzer, Ş. (in press). Assessing design. In Strobel, J., Cardella, M.E. & Purzer, Ş. (eds.), *Engineering in precollege settings: Research into practice*. Rotterdam, The Netherlands: Sense Publishers.



# Jennifer J. DeBoer

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*Dr. Jennifer J. DeBoer's research is situated at the critical intersection of engineering education, technology, comparative education policy, and development. She is motivated by the need for greater understanding of how contextual factors (sociocultural, physical, and economic characteristics of the learning environment) moderate the relationship between STEM education opportunities, formal and informal education, and development. Dr. DeBoer also serves as co-director of the International Institute for the Development of Engineering Academics (IIDEA), which is focused on establishing a global network of engineering faculty development programs to disseminate learning about the transformation of engineering education worldwide.*

**Investigating international engineering education systems** |→ Dr. DeBoer examines the varied structures of engineering education systems around the world. She has used detailed individual-level data from Brazil to understand how student background factors and institutional resources in the Brazilian system facilitate engineering achievement. Focusing on the South African engineering education system, Dr. DeBoer surveyed undergraduate students as they complete their degrees and prepare to enter the labor force. The cross-sectional data from the survey provide a useful representative look at, on average, the most important background factors for students, their perceptions of how well their programs prepare them to address local problems, and their future goals. In collaboration with colleagues in China, she is looking at the national system of university programs and nascent accreditation structures. Dr. DeBoer has extended this international line of inquiry with a comparative perspective to understand how STEM learning environments can be related and contrasted. Specifically, she serves as the co-PI for a comparative study of the participation of women in engineering in the United States and select majority-Muslim countries.

**Supporting diverse students** |→ How does the interaction between students' backgrounds and classroom environments support attainment and achievement in STEM fields? Dr. DeBoer studies factors such as a student's family income and education levels, gender and race/ethnicity, prerequisite content knowledge, and educational attitudes and aspirations. The goal is to see how diverse students can be better served—whether in their pursuit of STEM learning or in their use of novel learning technologies. One example is the effect of computer use for students in the bottom quartile of economic and socio-cultural status within each country.

Additionally, Dr. DeBoer has supported work investigating the success of under-represented minorities in university engineering programs. She investigated classroom factors such as infrastructure and physical resources, peer characteristics, and teaching practices to understand how these factors interact with background factors to support student success.





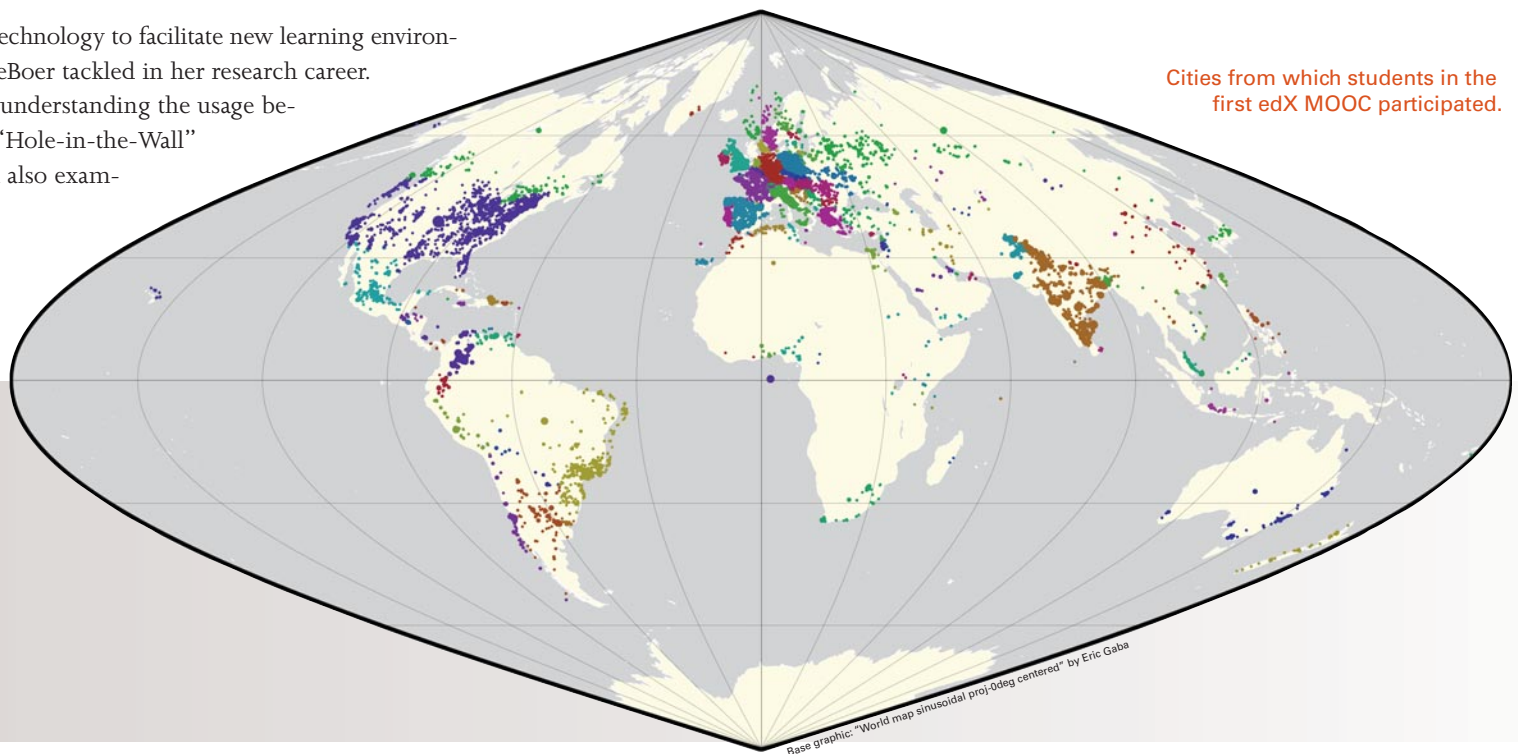
## Delivering learning opportunities through technology

↳ Dr. DeBoer has a strong foundation in terms of research, funding, and faculty development that looks specifically at the efficacy of new educational technologies. This includes an investigation of edX classes. As lead analyst, she was able to pose a host of important questions about the utility of the medium. Who is taking these classes? What resources “work,” and for whom? How do students connect to each other in this space? And, what is the nature of the online experience for residential students?

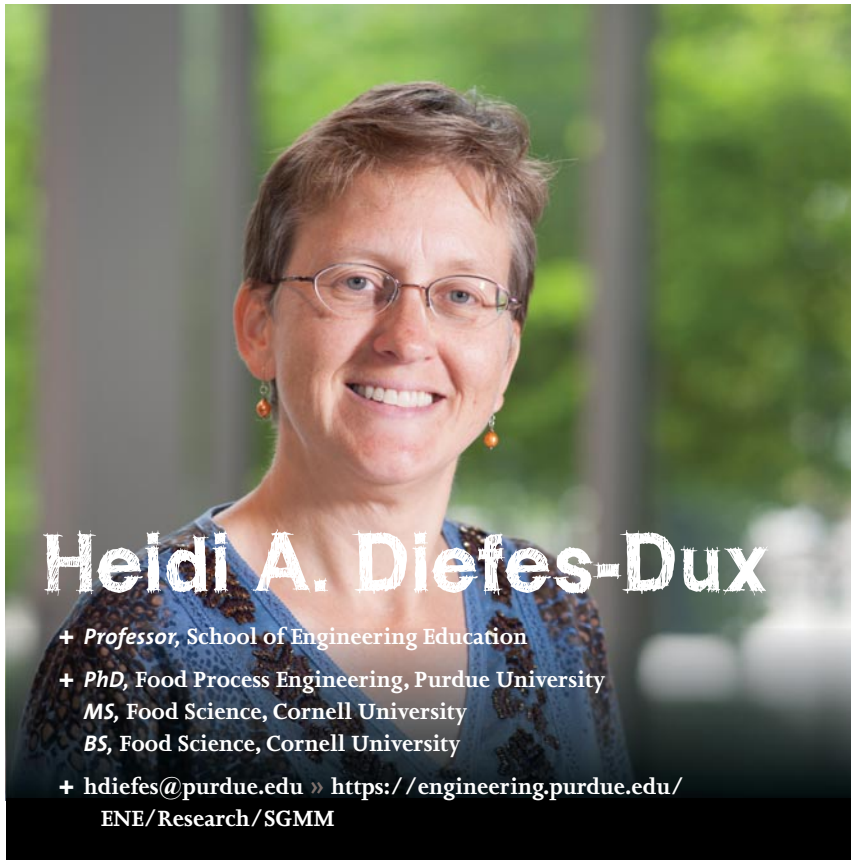
The question of the utility of technology to facilitate new learning environments is one of the first Dr. DeBoer tackled in her research career. She conducted early work on understanding the usage behaviors of students at Mitra’s “Hole-in-the-Wall” computers. Her early research also examined the effect of computer use in school, at home, and “elsewhere” on problem solving performance.

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**[FUNDING]** NSF DIVISION OF RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS;  
AMERICAN EDUCATIONAL RESEARCH ASSOCIATION



**KEY PUBLICATIONS** DeBoer, J., Ho, A.D., Stump, G.S., & Breslow, L. (2014). Changing “Course”: Reconceptualizing Educational Variables for Massive Open Online Courses. *Educational Researcher*, 43(2): 74-84. DeBoer, J. (2012). The Twentieth Century of American Education Reform in the Global Context. In *Peabody Journal of Education*, special issue, 87(4), eds., DeBoer, J. & Mavrogordato, M. DeBoer, J. (2013). The Student Platform for Engineering Education Development: Empowering, Connecting, and Diffusing Student Initiatives for Change. In *Educator’s Guide to Engineering and Social Justice*, ed. O’Shea, J. Australian Learning and Teaching Council Project, University of Western Australia.



## Heidi A. Diefes-Dux

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*Dr. Heidi A. Diefes-Dux is a national leader in the research-based development, implementation, and assessment of model-eliciting activities in engineering education. Her work recasts the models and modeling perspective that originated in mathematics education and creates a strategic, scalable approach for addressing crucial goals in engineering education. In addition, Dr. Diefes-Dux has pursued research with Purdue's Institute for P-12 Engineering Research and Learning (INSPIRE) that provides a foundation for equipping teachers to incorporate engineering concepts into elementary school classrooms.*

### Student learning through mathematical modeling activities

↳ The engineering workforce of the future must be prepared to address increasingly complex and ambiguous problems, yet effectively teaching open-ended problem-solving has been a challenge for engineering educators. Research in mathematical modeling activities, specifically model-eliciting activities (MEAs), aims to develop effective, transferable student competencies in problem-solving and creativity, as well as prompt more-effective learning and retention of important concepts, identify students' misconceptions, and nurture engineering habits of mind.

MEAs are authentic, open-ended, team-oriented problems set in engineering contexts that require, in the case of this research, first-year student teams to create generalizable mathematical models for direct users. Originally created to observe the development of student problem-solving competencies and the growth of mathematical cognition, MEAs have been increasingly documented as a method to help students become better problem solvers, as well as a tool to help both instructors and researchers better design situations to engage learners in productive mathematical thinking.

Dr. Diefes-Dux's work in this area is highly tied to actual classroom implementation. Two to four MEAs have been implemented and studied each Fall and Spring semester since Fall 2002 in a first-year engineering course with enrollments of up to 2,000 students. Data is collected *in situ*, with all the complications that characterize classroom teaching and learning. What is learned in one implementation cycle is fed directly into the next for continuous and documented improvement. Dr. Diefes-Dux's research group constantly (re)designs MEA instruction, instructor training, and MEA implementation strategies while collecting and analyzing data around each implementation and disseminating results.

Specific objectives include [1] expanding the MEA pedagogy, [2] studying students' problem-solving strategies and extending the use of MEAs to specific aspects of undergraduate reasoning and problem-solving, [3] determining the solution paths first-year engineering students use in solving MEAs, [4] executing a comprehensive dissemination and infusion effort, and [5] developing a comprehensive research agenda for models and modeling in undergraduate education.

Further research concerns the development of pedagogical approaches for providing formative feedback from peers and teaching assistants. The latter is a step toward growing a community of engineering educators who are better able to teach open-ended complex problems. Principles and guidelines for providing effective feedback will greatly facilitate the dissemination of models and modeling pedagogies to other educational settings.

### Professional development of elementary school teachers

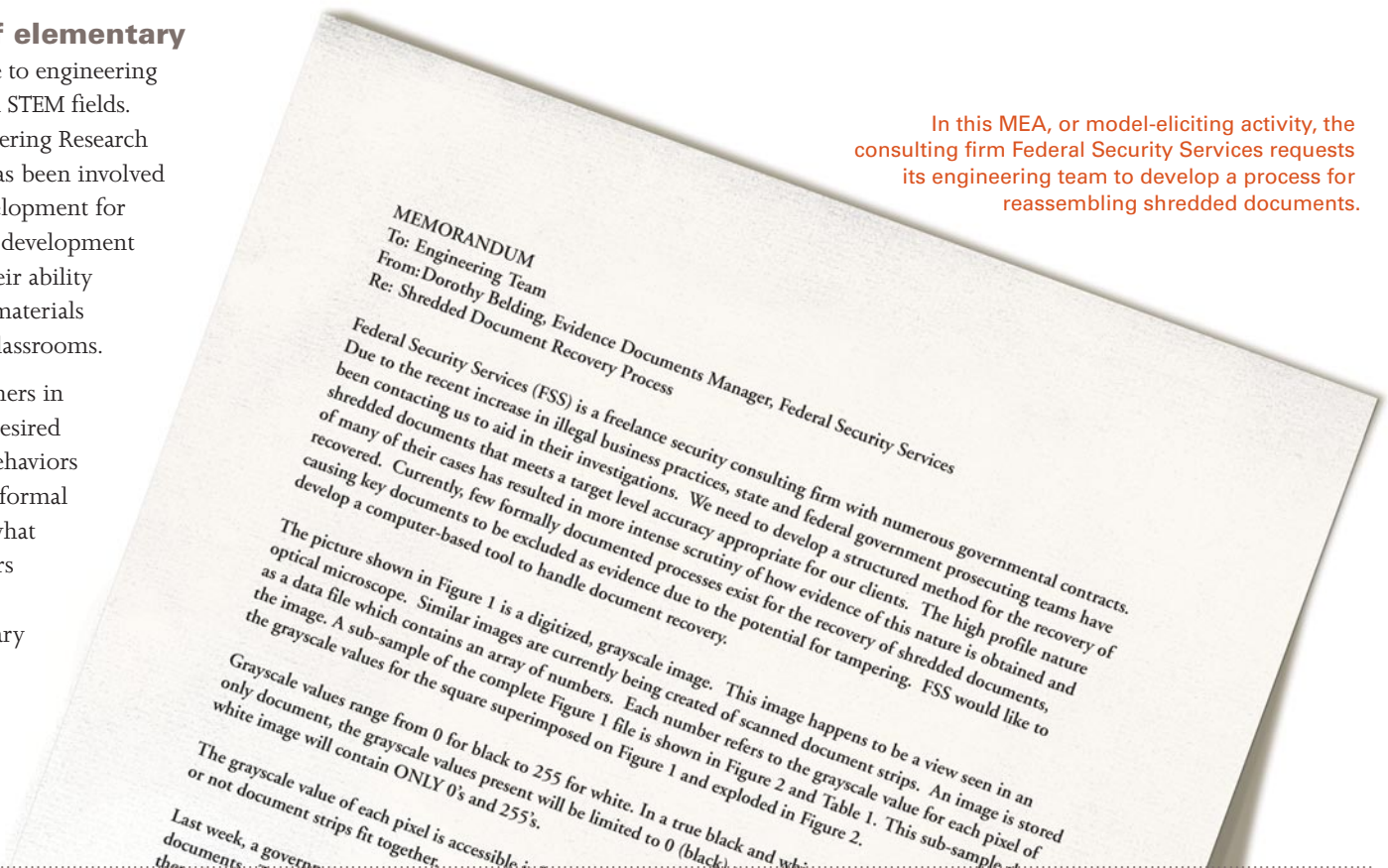
→ Early exposure to engineering principles may increase students' interest in STEM fields. Through Purdue's Institute for P-12 Engineering Research and Learning (INSPIRE), Dr. Diefes-Dux has been involved in research that supports professional development for elementary school teachers, including the development of a learning progression that increases their ability to adopt and refine engineering learning materials for use in second- through fourth-grade classrooms.

One study, which involves about 120 teachers in four cohort groups, seeks to identify the desired set of student knowledge, attitudes, and behaviors as a result of integrating engineering into formal elementary education, and to determine what teacher knowledge, attitudes, and behaviors are necessary for successful and sustained integration of engineering in the elementary classroom.

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[FUNDING] NSF DIVISIONS OF ENGINEERING EDUCATION AND CENTERS AND OF RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS

In this MEA, or model-eliciting activity, the consulting firm Federal Security Services requests its engineering team to develop a process for reassembling shredded documents.



**KEY PUBLICATIONS** Diefes-Dux, H.A. & Imbrie, P.K. (2008). Chapter 4: Modeling activities in a first-year engineering course. In Zawojewski, J.S., Diefes-Dux, H.A. & Bowman, K.J. (eds.), *Models and modeling in engineering education: Designing experiences for all students* (pp. 55-92), ISBN 978-9087904029. Diefes-Dux, H.A., Zawojewski, J.S. & Hjalmanson, M.A. (2010). Using educational research in the design of evaluation tools for open-ended problems. *International Journal of Engineering Education*, 26(4), 807-819. Diefes-Dux, H.A., Zawojewski, J.S., Hjalmanson, M.A. & Cardella, M.E. (2012). A framework for analyzing feedback in a formative assessment system for mathematical modeling problems. *Journal of Engineering Education*, 101(2).





## Allison F. Godwin

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As a chemical engineer with industry experience, Dr. Allison F. Godwin knows first-hand the engineering workforce and the need for it to become more diverse. Her research focuses on increasing female enrollment in engineering, how students' attitudes and beliefs affect their choices and their learning, and how to improve engineering education for all students – especially those from underrepresented groups. Dr. Godwin is the recipient of a 2014 American Society for Engineering Education (ASEE) Educational Research and Methods Division Apprentice Faculty Grant. She also was an NSF Graduate Research Fellow for her work on female empowerment in engineering.

**How identity affects choices** |→ By understanding how students' attitudes and beliefs affect their choices and their learning, Dr. Godwin is working to address the shortfall in women earning engineering bachelor's degrees. She used *Critical Engineering Agency*, a framework which she developed and validated during her research, to understand the persistent issue of female underrepresentation in engineering. Understanding identity development over time can give insight into how students become engineers from choosing engineering in college to graduation. A community of practice in engineering aids in the development of identity through students becoming part of a specific professional culture, students' growth in conceptual knowledge of a field, and students' development of a sense of belongingness or affiliation with their vocation.

**Perceived impact of STEM careers** |→ Dr. Godwin's research has included the construction of structural equation models to explain students' choice of engineering in college. That is based on how students identify with math and science as well as their beliefs about what a STEM career can accomplish. She also worked to understand these connections through a qualitative open-ended survey and interviews. Her analysis of the data can help to explain the ways in which some students do not identify with engineering and offer ways to remedy the low recruitment and retention rates amongst engineering majors. This work also can highlight ways in which women identify with engineering to help make engineering a better fit with their desired career goals.

**Developing engineering identity in college** |→ While students' identities may change with an engineering community of practice, they will still hold specific identities. Dr. Godwin plans to study how students' physics and math identities are incorporated into the development of that new engineering identity. The framework of *Critical Engineering Agency* is valuable to explain who students think they are and the empowered actions that they take within the world. She hopes to conduct a longitudinal study of engineering students from their freshman year to graduation on how their identities change within a community of practice. The data for this study will include multiple student case-studies as well as survey data in a concurrent mixed-methods longitudinal study. This data can be analyzed through both quantitative and qualitative data analysis to understand general trends as well as causal reasons for identity and empowerment shifts.

## Belongingness of non-normative groups in engineering

Traditional engineering culture limits rather than fosters diversity in engineering. To address this issue, Dr. Godwin proposes to study how students identify themselves and navigate the culture of engineering. Traditional definitions of diversity in engineering education constrain students' identities to certain norms with which they may not actually identify, and limit insight into students at the intersection of multiple identities. Additionally, describing intersectionality as the meeting point between gender, race/ethnicity, and sexual orientation limits a comprehensive understanding of non-normative identities in engineering by imposing socio-cultural labels which sort students into predefined categories rather than allowing for an emergent understanding. Dr. Godwin will investigate the emergent intersectionality of students' identities to understand: How do non-normative groups in engineering form an engineering identity and navigate a culture dominated by heteronormativity and limited diversity? This approach should capture complex interactions between students' identities and the culture of engineering, as well as how non-normative identified students navigate engineering, and how to recruit, retain, and include these students in engineering.

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**[FUNDING]** NSF GRADUATE RESEARCH FELLOWSHIP; NSF GRADUATE RESEARCH ASSISTANT; NSF DIVISION OF HUMAN RESOURCE DEVELOPMENT

**“One of my research interests is to work to address the need for more women in engineering by understanding how their attitudes and beliefs as students affect their choices and their learning.”**



**KEY PUBLICATIONS** Allison Godwin, Geoff Potvin, Zahra Hazari, and Robynne Lock. Identity, Critical Agency, and Engineering Majors: An Affective Model for the Choice of Engineering in College. *Journal of Engineering Education* (Submitted), 2014. Leidy Klotz, Jennifer Cribbs, Allison Godwin, Robynne Lock, Geoff Potvin, and Zahra Hazari. Sustainability as a Route to Broaden Participation in Engineering. *Journal of Engineering Education*, 103(1):137–153, 2014. Allison Godwin and Geoff Potvin. Chemical Engineering Students: A Distinct Group Amongst Engineers. *Chemical Engineering Education*, 47(3):145–153, 2013.



*As executive director of Purdue's Engineering Professional Education program, Dr. Dale A. Harris oversees an academic enterprise that offers 61 master's-level courses online to more than 1,300 degree- and non-degree-seeking engineers and technical professionals in 41 U.S. states and 15 countries. In this role, he pursues research on the use of high-speed networks and the internet in teaching and learning, with particular emphasis on distance education. He is a 1996 co-recipient of the U.S. Distance Learning Association's award for the most significant advancement in research in the field of distance learning. In 1999 he and Bjorn Pehrson of the Royal Institute of Technology were finalists for the Bangemann Global Challenge Prize for innovative use of information technology in education.*

### **Online education and blended learning environments**

↳ With the emergence of worldwide communications networks and powerful computer technologies, the number of online learners has increased from nearly none in 1995 to well over 6 million by 2012. Concurrently, the concept of distance learning—once confined to correspondence courses or televised classes—and the delivery of engineering education content online have been redefined.

As an academic and a member of the Sloan Consortium, an organization supported by the Alfred P. Sloan Foundation and committed to making learning available to anyone, anywhere, anytime, Dr. Harris has provided leadership in improving online learning and analyzing implementations that increase the quality of online courses, improve our ability to scale to larger populations, and improve the breadth of coverage of engineering courses. He has participated in two invited papers, assessing (with co-authors) the state of online engineering education, recommending future directions, and highlighting five important components of online learning quality (see figure), thus establishing a fundamental framework for gauging progress in implementing effective online learning opportunities.

Through a Sloan Foundation grant to Purdue's Engineering Professional Education program, Dr. Harris led an initiative that used blended learning environments to support lifelong learning in Indiana's manufacturing industry through the Indiana Advanced Manufacturing Education Collaborative. Blended learning environments combine a variety of delivery formats, from face-to-face learning in the classroom to podcasted courses to online courses using tools such as threaded discussion boards.

Refocusing elements of existing courses and programs from face-to-face instructional environments to blended ones resulted in increased access, learning effectiveness, student and faculty satisfaction, and cost-effectiveness. New courses and programs also were developed that addressed industry needs.

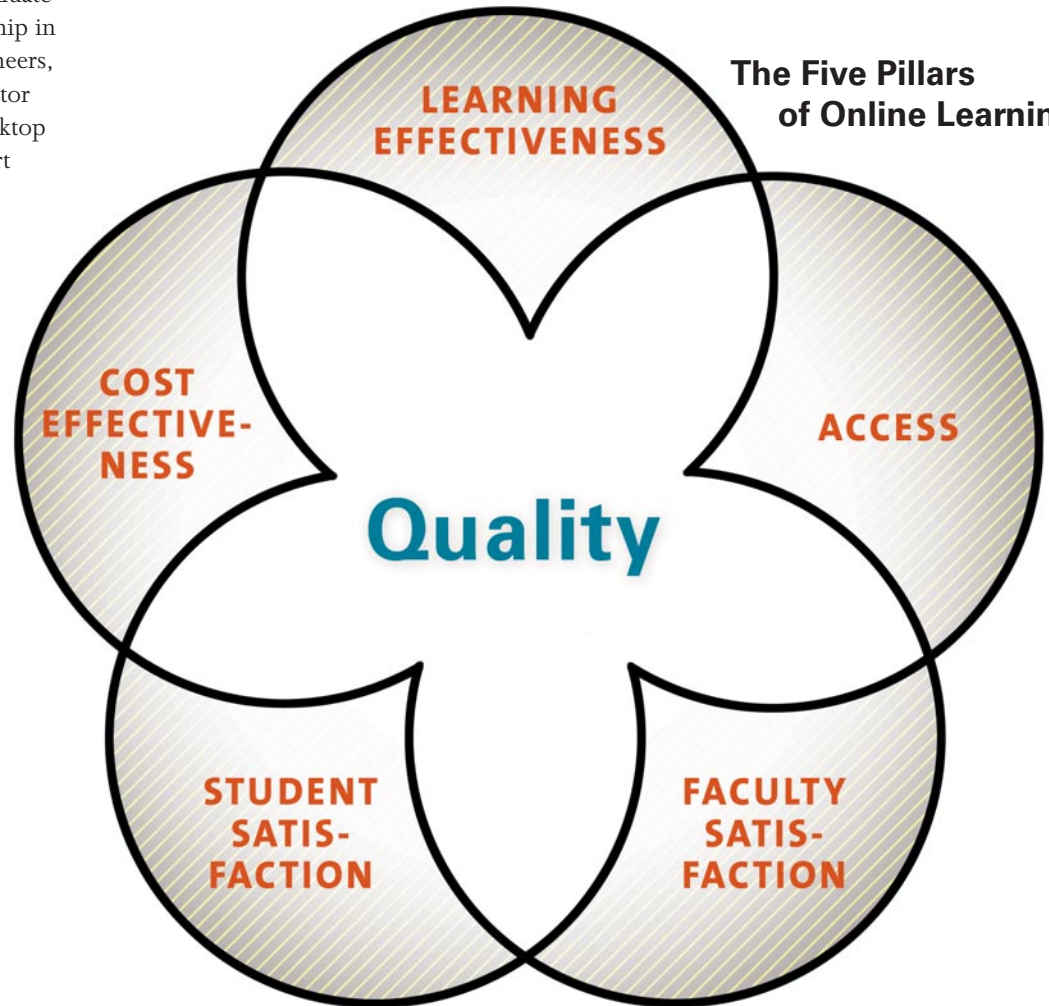
Using the blended format is primarily justified, the research demonstrates, for the convenience of the student and/or instructor. Instructors highly valued blended delivery when some face-to-face contact was desired but fully face-to-face delivery was impossible because of logistical restraints. Results suggest that blended courses and programs will fill an important niche complementing Purdue's other professional education programs.



**Globalization and engineering** |→ Dr. Harris combines his academic interests in distance education and in globalization in his graduate-level course “Globalization and Engineering.” Informed by his scholarship in distance education, the course is taught at a distance to employed engineers, almost all of whom have global work experience. In addition to instructor lectures and textbooks, students use asynchronous chat boards, live desktop conferencing, and bidirectional multimedia recording/streaming as part of a fully collaborative learning experience.

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[FUNDING] ALFRED P. SLOAN FOUNDATION



**KEY PUBLICATIONS** Bourne, J., Harris, D.A. & Mayadas, F. (2005). Online engineering education: Learning anywhere, anytime. *Journal of Engineering Education*, 94(1), 131-146. Harris, D.A. & Krousgrill, C. (2008). Distance education: New technologies and new directions. *Proceedings of the IEEE*, 96(6). Gutierrez, D., Harris, D.A. & Shah, A. (2002). Stanford researchers prepare to use Internet2 to train medical students, *CENIC Today*, 5(3).



## Morgan M. Hynes

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*Dr. Morgan Hynes does work in promoting the vision that all students have a chance to engage in engineering. His research and outreach work promotes broadening the contexts of engineering and design activities in kindergarten through college settings with the aim of supporting all students—people with diverse backgrounds and interests, especially those underrepresented in engineering—in making personally meaningful connections to engineering. He employs qualitative research methods that allow in-depth study of how students engage—lose themselves in the activity, authentically applying their skills and knowledge—in myriad practices of engineering—developing solutions for and with people to improve the quality of life.*

### Engaging K-12 learners in engineering for and with people

↳ Dr. Hynes' research argues for the systematic inclusion of social science and humanities knowledge in engineering for K-12 students, and he has developed illustrative examples of what appealing to the humanistic side of engineering can look like in a classroom setting. These examples are drawn from interactions among student teams from elementary classrooms engaged in engineering activities that demonstrate that engineering is about solving problems *for* people *with* teams of people. This work has yielded ideas for research in the education of K-16 students, including work in understanding students' attitudes, beliefs, and perceptions, particularly among traditionally underrepresented populations, and in exploring how students' engineering knowledge and practices develop in the context of a people-centered approach to engineering.

Work on integrating engineering and literacy in elementary classrooms has used children's fiction—typically focusing on problems that characters are facing—as rich context for students to design something for the characters. Research questions include: What do the beginnings of engineering look like in the elementary setting? Does providing a literary context support engineering design practices? The people-centered approach not only portrays engineering as a caring profession but also highlights women and people of color as engineers, in order to broaden perceptions of who can be an engineer.

### Engineering and design in K-12 settings

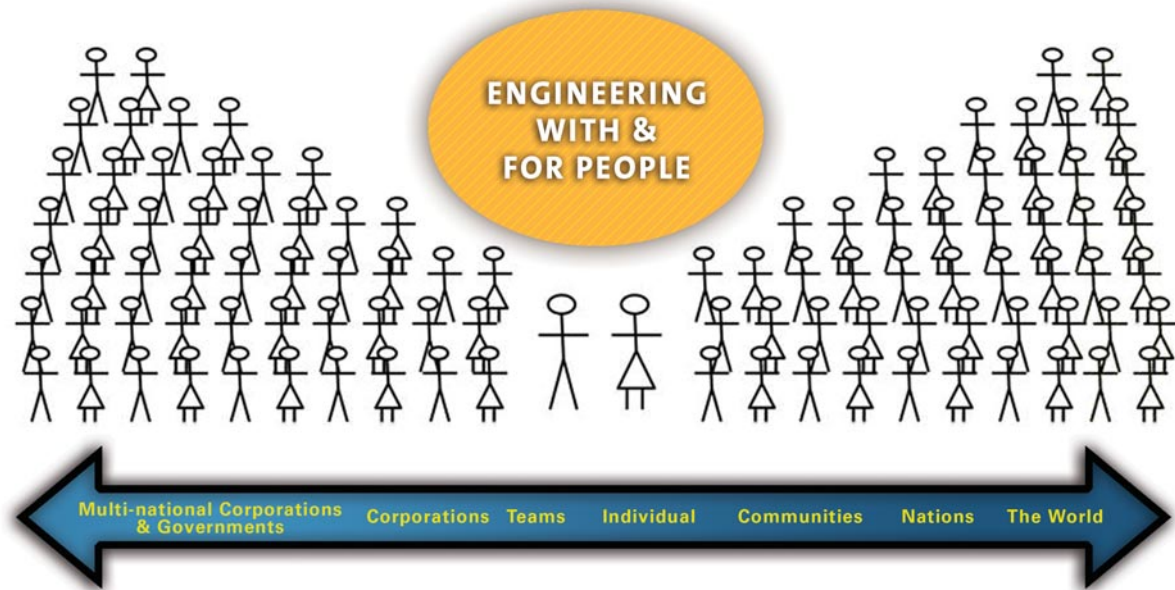
↳ In addressing the problem of preparing Massachusetts middle school mathematics, science, and computer teachers to teach engineering, Dr. Hynes focused his research on the teachers' instruction and knowledge of the central aspects of the engineering design process (EDP)—the purpose of the EDP; that the EDP is a cyclical, iterative process; and that the EDP fosters communication. The analysis of videotaped classroom observation data revealed that the teachers as a group covered the central ideas regarding *the purpose of the EDP* and *EDP as a cyclical process* quite well, but did not cover *EDP for fostering communication* well. The research explores each central idea and the teachers' understandings of them as expressed through their explanations in the classroom observations and follow-up interviews.



## How teachers and students conceptualize engineering and design

→ Dr. Hynes' research aims to understand how students' and teachers' engagement in engineering activities influences how they conceptualize the engineering design process. Like any model, an engineering design process is a representation distilled from observing people in action. Dr. Hynes' approach is first to engage students and teachers in doing engineering, then have them reflect on their work, come up with their own model, and compare that to an existing model. The model becomes more ingrained in students because it derived from their own actions and experiences.

[FUNDING] NSF DIVISIONS OF RESEARCH ON LEARNING AND UNDERGRADUATE EDUCATION; NASA



**KEY PUBLICATIONS** Hynes, M. M., & Swenson, J. (2013). The Humanistic Side of Engineering: Considering Social Science and Humanities Dimensions of Engineering in Education and Research. *Journal of Pre-College Engineering Education Research*, 3(2), 31-42. Hynes, M. (2012). Middle-school Teachers' Understanding and Teaching of the Engineering Design Process: A Look at Subject Matter and Pedagogical Content Knowledge. *International Journal of Technology and Design Education*, 22, 345-360. Hynes, M. M. (2012). Middle Grades Teachers' Understanding And Teaching Of The Central Ideas Of The Engineering Design Process. *Advances in Engineering Education*, 3(2), 1-21.





## Brent K. Jesiek

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*Nationally recognized for his research on global engineering, Dr. Brent K. Jesiek draws on expertise in engineering, computing, and the social sciences to improve our understanding of geographic, disciplinary, and historical variations in engineering education and professional practice. The objectives of his teaching and research include enhancing the ability of current and future engineers to work more effectively in an increasingly complex, diverse, interdisciplinary world and supporting the continued development of engineering education as a scholarly community and research field.*

**Global engineering** |→ Dr. Jesiek’s multifaceted work on global engineering responds to widespread calls to expand and improve global learning opportunities for engineering students and professionals. This research begins with establishing empirically based definitions of global competency for engineers, then turns to question how students and professionals learn to work in diverse, multicultural contexts. Related historical and social studies help students and professionals better understand and interact with different national cultures of engineering, while also contextualizing recent efforts to scale up global engineering education. An important third dimension of this research area involves assessment, including through the use of preexisting survey instruments to study cross-cultural competence and the development and validation of new instruments to measure other dimensions of global competency that are partially or wholly specific to engineering practice.

Specific initiatives include Dr. Jesiek’s work on the International Research and Education in Engineering (IREE) program. Funded by NSF and administered by Purdue University, IREE 2010 sent 58 U.S. undergraduate and graduate engineering students to China for intensive 10-week research experiences in university and industry laboratories. The program also featured extensive pre-departure and on-site orientation activities, a new Engineering Cultures China curriculum, a two-day re-entry meeting, extensive use of the GlobalHUB cybercommunity, and systematic assessment of the program’s outcomes and impacts.

Additional research is under way. For instance, Dr. Jesiek (along with Co-PI Sang Eun Woo) has received NSF support for a project titled “Global Engineering Competency: Definitions, Development Paths, and Situational Assessment.” The primary outcome of this work is a valid and reliable Situational Judgment Test (SJT) that assesses three to four major dimensions of global engineering competency in five distinct regions/contexts. By establishing a means to measure global competence and then widely distributing the resulting instrument, the project will help engineering programs develop courses and curricula that more effectively prepare students for the global realities of engineering practice. This project also represents a cutting-edge effort to utilize situational and scenario-based assessment strategies in engineering education.

## Capacity building and analytics in engineering education research

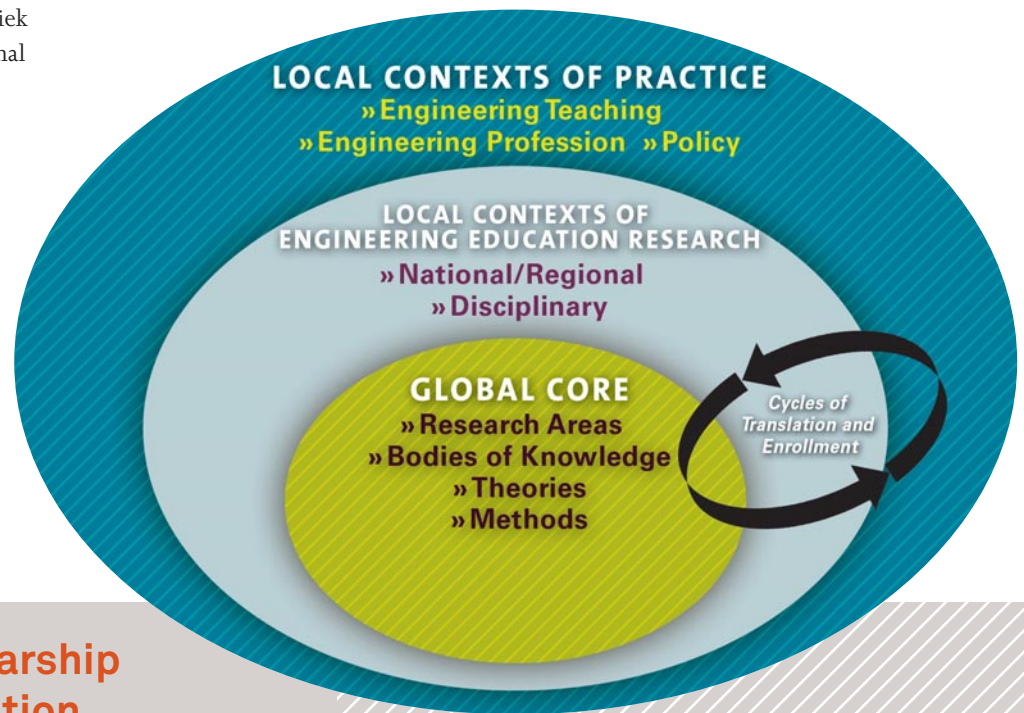
→ A leader in systematically studying and promoting the development of engineering education as a field, both in the U.S. and abroad, Dr. Jesiek uses social science insights and advanced information technologies to build local and global networks of engineering education researchers, scholars, and practitioners. In reporting on the Advancing Global Capacity for Engineering Education Research initiative, for example, Dr. Jesiek and colleagues analyzed findings from 10 moderated sessions at international engineering education conferences in 2007 and 2008 where participants discussed the current state and future trajectory of engineering education. Using thematic analysis techniques, this work yielded important insights about how engineering education research is related to teaching practice, educational policy, and industry needs—including across regions. These findings in turn informed the creation of a cyclic model to strategically enhance these kinds of relationships.

In a series of related studies, Dr. Jesiek has also pioneered use of “meso-scale” analytic approaches to examine the development and state of engineering education as a field. In addition to looking at research and publication trends in general, this work has investigated levels of activity in specific research areas such as gender and diversity, problem- and project-based learning, and electrical engineering education.

## Advancing engineering education scholarship locally and globally via cycles of translation and enrollment

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[FUNDING] NSF DIVISIONS OF ENGINEERING EDUCATION AND CENTERS AND OF UNDERGRADUATE EDUCATION



**KEY PUBLICATIONS** Jesiek, B.K., Shen, Y. & Haller, Y. (2012). Cross-cultural competence: A comparative assessment of engineering students. *International Journal of Engineering Education*, 28(1), 144-155. Jesiek, B.K. & Beddoes, K. (2010). From diplomacy and development to competitiveness and globalization: Historical perspectives on the internationalization of engineering education. In Downey, G.L. & Beddoes, K. (eds.), *What is global engineering education for?: The making of international educators* (pp. 45-76), ISBN 978-1608455430. Jesiek, B.K., Borrego, M. & Beddoes, K. (2010). Advancing global capacity for engineering education research (AGCEER): Relating research to practice, policy, and industry. *Journal of Engineering Education*, 99(2), 107-119.



Together with undergraduate and graduate students, Dr. Michael C. Loui conducts research in the scholarship of teaching and learning, engineering education, and ethics in engineering and computing. He is broadly interested in affective outcomes of engineering instruction. His “big question” is: What pedagogies promote student motivation, confidence, and persistence? Prior to joining the faculty at Purdue, he was a professor of electrical and computer engineering at the University of Illinois at Urbana-Champaign, where he also served as an associate dean of the Graduate College. Dr. Loui is the inaugural Dale and Suzi Gallagher Professor of Engineering Education and serves as editor of *Journal of Engineering Education*. He is a Carnegie Scholar and an IEEE Fellow.

**Motivation and persistence** |→ No matter the discipline, all engineering undergraduate students must take required courses. While these courses cover engineering science principles necessary in their education, they usually lack a connection to actual products and societal problems. Dr. Loui and his colleagues are working to promote intrinsic motivation in required courses by supporting student autonomy, mastery and relatedness—the three components of the self-determination theory of motivation. Data collection methods included a concept inventory, a motivation survey, and individual interviews.

In related work, Dr. Loui is part of a team studying grit—a combination of perseverance and a passion for long-term goals. They are investigating: 1) What does grit look like for engineering students? 2) Can we improve engineering students’ grit? 3) Does the grit scale predict retention among first-year engineering students? This study will show how noncognitive factors could play an important role in the persistence of engineering students.

**Self-efficacy in engineering laboratories** |→ Dr. Loui is part of a team working to improve the self-efficacy of students in an introductory engineering laboratory courses. They developed a collaborative learning technique called structured pairing, in which a pair of students alternates between two roles in a laboratory session: one student performs hands-on tasks while the other student records measurements and checks for errors; students switch roles every 20 to 30 minutes. The researchers found that structured pairing improves students’ confidence with laboratory work and satisfaction with team experiences. For a general education course in engineering for nontechnical students, the researchers developed a new pedagogy called diversity harnessing. The idea is to direct the diverse interests of the students back into the course materials—lecture topics, homework and exam problems, and labs. The goals of this project are to better engage the students in the course topics and to empower the students to more effectively apply new skills to their lives and careers.

**Professional ethics and identity development** |→ How do engineering students develop professional identities—specifically, their understanding of professional responsibility? Dr. Loui and other researchers interviewed students who recently completed a course on engineering ethics and those who



had not taken the course. Each interview elicited what the student would do in two scenarios as an engineer facing an ethical issue. Dr. Loui also studied the impact of the ethics course on students' understandings of professional responsibility and on the development of their engineering identities.

### **Mentoring relationships in academic research** |→

Many studies have shown the positive effects of mentoring on students. However, there is little research examining the way a mentoring relationship develops over time. Dr. Loui and colleagues are studying the development of the relationship between graduate student mentors and undergraduate student researchers. Rather than looking at the relationship at a single point in time,

their NSF-funded study examines how the mentoring relationship can and should change over time. They have created a model that explains some conflicts that can arise in the mentoring relationship.

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**[FUNDING]** NSF DIVISION OF UNDERGRADUATE EDUCATION; NSF ETHICS EDUCATION IN SCIENCE AND ENGINEERING PROGRAM; NSF RESEARCH EXPERIENCES FOR UNDERGRADUATES PROGRAM; IEEE FOUNDATION



**“Although I have previously investigated cognitive outcomes of engineering instruction, such as misconceptions in digital logic, I am most interested in affective outcomes—both intended and unintended.”**

**KEY PUBLICATIONS** Fila, N. D., & Loui, M. C. (2014). *Structured pairing in a first-year electrical and computer engineering laboratory: The effects on student retention, attitudes, and teamwork*. International Journal of Engineering Education, 30(4), 848-861. Herman, G. L., Kaczmarczyk, L., Loui, M. C., & Zilles, C. (2012). *Describing the what and why of students' difficulties in Boolean logic*. ACM Transactions on Computing Education, 12(1), article 3. Herman, G. L., Zilles, C., & Loui, M. C. (2012). *Flip-flops in students' conceptions of state*. IEEE Transactions on Education, 55(1), 88-98. Loui, M. C. (2009). *What can students learn in an extended role-play simulation on technology and society?* Bulletin of Science, Technology & Society, 29(1), 37-47.



## Krishna P.C. Madhavan

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*A 2008 NSF CAREER Award recipient and an invited participant in the National Academy of Engineering's 2009 Frontiers of Engineering Education symposium, Dr. Krishna P.C. Madhavan conducts frontier research at the intersection of engineering education and cyberinfrastructure. Using advanced data collections, data analysis, and visualization tools, he aims to personalize learning within engineering cyber-environments. His work using "dark data" allows novices in data mining and visualization to interactively analyze collaborative networks as means of propagating innovative ideas among engineering education researchers.*

### Personalizing and assessing engineering cyber-environments

↳ How can cyber-tools and cyber-environments better enable learning in the engineering and, more broadly, STEM disciplines? In his CAREER Award-related research, Dr. Madhavan combines learning theories (focusing on the student learning experience) and semantic web design (characterizing and creating cyber-environments) to understand educators' expectations of cyber-tools and cyber-environments as engineering teaching tools and to characterize and optimize how undergraduate learners interact with simulation tools online.

When users interact with an engineering cyber-environment like nanoHUB.org, their patterns of behavior online reflect their goals and levels of expertise (novice to expert) in using that environment. Dr. Madhavan's work aims to identify user types and their emergent behaviors early on and develop methods for orienting the content, services, and resources within a cyber-environment to allow better learning (and indeed research productivity). In close collaboration with Purdue's nanoHUB team, his work focuses on developing new techniques known as user flow informatics, wherein the learning environment attempts to understand learners as they flow through the environment. His work is also establishing new paradigms for more fully understanding the research and educational impact of engineering cyber-environments using theoretical frameworks that include more holistic, system-wide analyses of platform data that utilize scientometric, bibliometric, and sociometric indicators.

### Capacity building in engineering education research

↳ Scientific problem spaces like engineering and STEM education are prolific and fast-changing. The engineering education and STEM education research communities are producing a tremendous amount of knowledge, but where is it coming from? How is it being diffused? How are communities, organizations, and individuals using knowledge about engineering education practices and research? Only by discovering scientific methods to describe, characterize, and comprehend all of the "dark data" around the problem space of engineering education—that is, data that isn't systematically organized for search and analysis—can we truly answer these questions. Building on an NSF-funded prototype known as the iKNEER (Interactive Knowledge Networks for Engineering Education Research) platform, Dr. Madhavan's DIA2 (Deep Insights Anytime, Anywhere)



# The Collaboration Network among NSF CCLI Awardees (1998-2011)

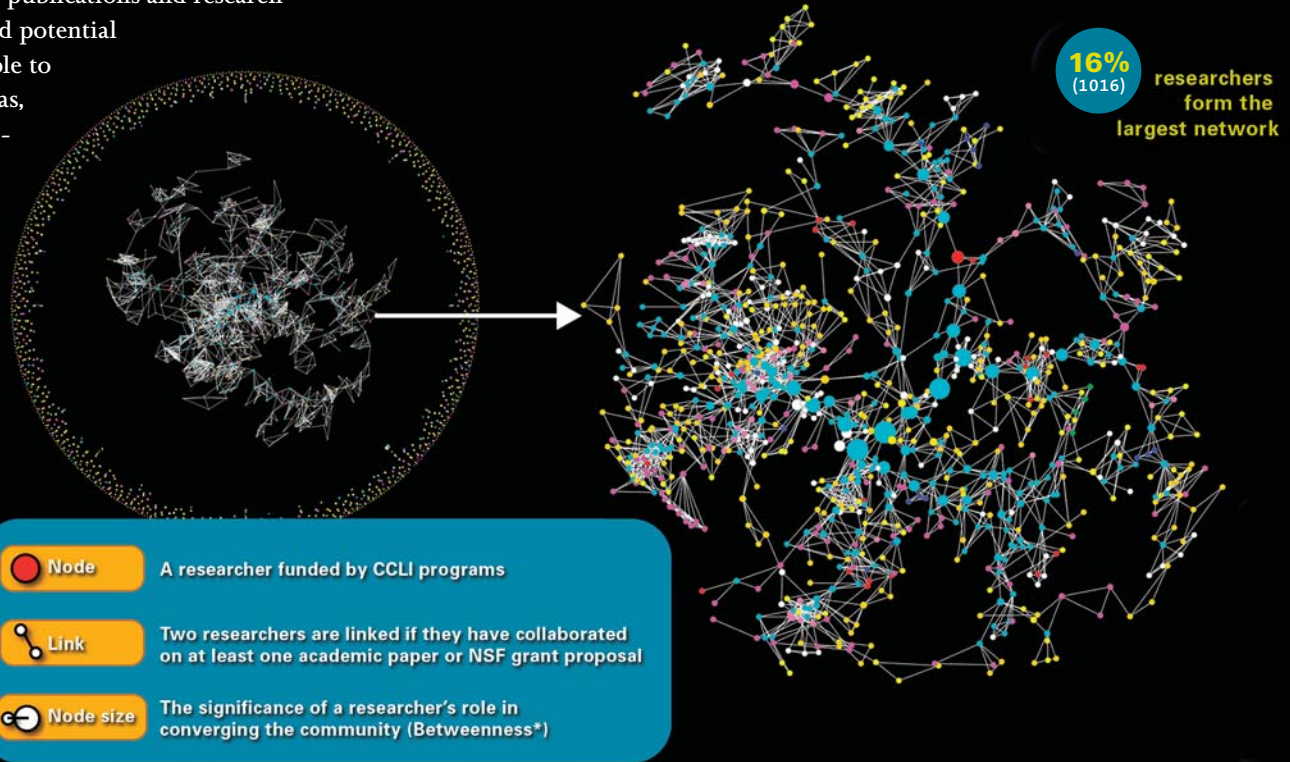
Based on Academic Publications and NSF Grant Proposals Archived by DIA2

project will provide a new way for people working on improving STEM research to synthesize knowledge produced through NSF and other federal investments.

DIA2 is designed to allow researchers and NSF program officers to identify, through a web-based knowledge portal, trends in publications and research funding, gaps in current research and funding, and potential collaborators in STEM education. Users will be able to quickly determine who is working in specific areas, their collaborators, funding sources, program officers, research papers, and findings. The system visualizes complex networks of funding and research collaborations with a map created anew for each search. The network maps contain clickable nodes that yield further layers of information leading to a new way for navigating through large and complex datasets.

Combining theories of user-centered design, large-scale data mining, community formation, social network analysis, and interactive visualization, DIA2 promises to accelerate the pace of innovations and their diffusion into widespread use.

**[FUNDING]** NSF DIVISIONS OF ENGINEERING EDUCATION AND CENTERS AND OF UNDERGRADUATE EDUCATION



**KEY PUBLICATIONS** Madhavan, K.P.C., Xian, H., Johri, A., Vorvoreanu, M., Jesiek, B.K. & Wankat, P.C. (2011, June). Understanding the engineering education research problem space using interactive knowledge networks. *Proceedings of the American Society of Engineering Education*, Vancouver, BC. Johri, A., Wang, A., Liu, X., & Madhavan, K.P.C. (2011). Utilizing topic modeling techniques to identify emergence and growth of research topics in engineering education. *Proceedings of the IEEE Frontiers in Education*, Rapid City, SD. Klimeck, G., Adams III, G.B., Madhavan, K.P.C., Denny, N., Zentner, M.G, Shivarajapura, S., Zenter, L.K. & Beaudoin, D.L. (2011). Social networks of researchers and educators on nanoHUB.org. *Proceedings of the Workshop on Social Networks (SN4CCGridS), IEEE/ACM International Symposium on Cluster, Cloud, and Grid Computing (CCGrid)*, Newport Beach, CA.





## Joyce B. Main

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*A Fellow of the 2014 Houston Higher Education and Finance Roundtable and the 2013 National Data Institute with the Association for Institutional Research, Dr. Joyce B. Main conducts research on factors that influence the academic and employment outcomes of science and engineering students. Her research focuses on engagement of students from a broad range of backgrounds, particularly at critical transitions between postsecondary education and career formation. Dr. Main applies her expertise in higher education policy to inform the design of programs and policies to support student academic success, professional development, and attainment of post-graduation employment.*

**Access to cooperative education programs** |→ With funding provided by the National Science Foundation, Dr. Main is examining variation in student access and participation in cooperative (co-op) education programs. A co-op in engineering is a partnership between an academic institution and an employer designed to engage students in practical engineering experience through rotations of full-time employment and course study. While much is known about the value of co-op participation, relatively little is known about why there are different rates of participation by race/ethnicity and how recruitment and pre-screening practices influence the diversity of students who participate in co-op programs. The objectives of this research strand are to identify factors that influence student access to cooperative education programs and to determine the educational and employment returns associated with participation. The comprehensive findings can be used to enhance co-op programs and policies to engage a broader range of engineering students to acquire potential academic and employment benefits.

**Career pathways for science and engineering doctorates** |→ The goals of this research strand are twofold: (1) to engage students from a broad range of backgrounds and experiences to pursue and complete doctorates in science and engineering (S&E), and (2) to diversify the composition of the engineering professoriate. Using comprehensive survey and longitudinal administrative data from two research-intensive institutions, Dr. Main is investigating factors that influence the graduation probability of S&E doctoral students and their subsequent career trajectories. She is particularly interested in the role of mentorship in academic persistence among women doctoral students.

Further, Dr. Main is analyzing data from the National Study of Postsecondary Faculty and the National Science Foundation's Survey of Doctorate Recipients to elucidate the career patterns of S&E doctorates. Funded by the American Educational Research Association, this research examines how institutional factors, such as the provision of paid parental leave and subsidized childcare, intersect with family formation to influence the career trajectories and progression of S&E doctorates. Findings have the potential to help shape institutional policies to facilitate work-life integration among faculty.



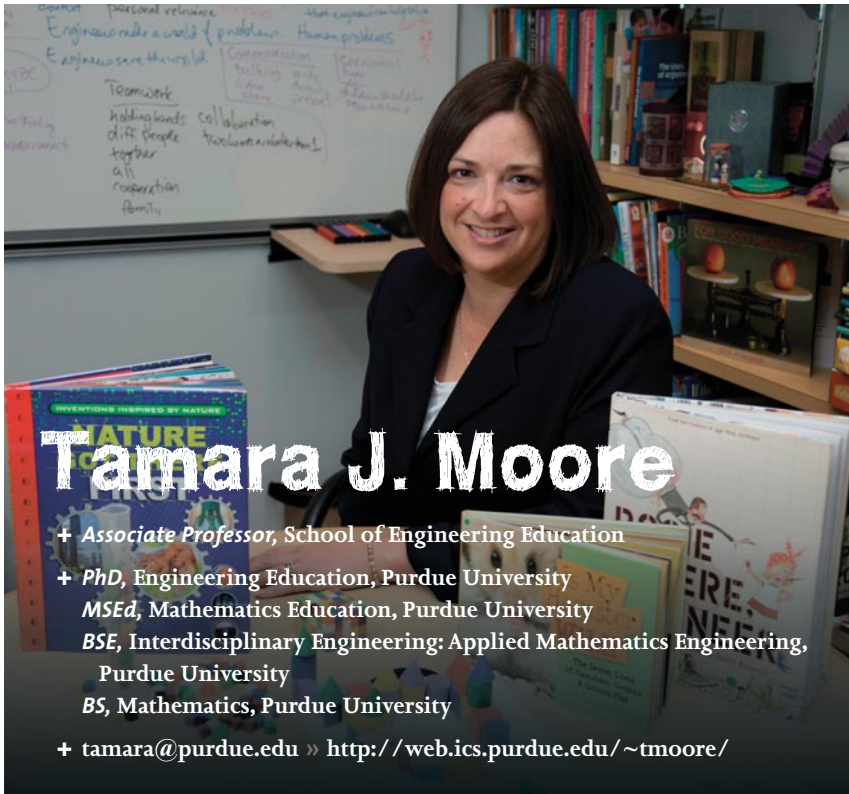
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**[FUNDING]** AMERICAN EDUCATIONAL RESEARCH ASSOCIATION GRANTS PROGRAM, NATIONAL SCIENCE FOUNDATION PARTNERSHIPS FOR INTERNATIONAL RESEARCH AND EDUCATION (PIRE), NATIONAL SCIENCE FOUNDATION RESEARCH IN ENGINEERING EDUCATION (REE)

## Social Policy and Higher Education Research in Engineering

The SPHERE Laboratory engages in empirical research to advance programs and policies for improving student academic and employment outcomes.

**KEY PUBLICATIONS** Main, J.B. (2014). Gender Homophily, Ph.D. Completion, and Time to Degree in the Humanities and Humanistic Social Sciences. *The Review of Higher Education* 37(3): 349-375. Main, J.B. & B. Ost. (2014). The Impact of Grades on Student Effort, Course Selection, and Major Choice: A Regression-Discontinuity Analysis. *Journal of Economic Education* 45(1): 25-35. Ehrenberg, R.G., Jakubson G.H., Martin, M.L., Main, J.B., and T. Eisenberg. (2012). Diversifying the Faculty Across Gender Lines: Do Trustees and Administrators Matter? *Economics of Education Review* 31(1): 9-18.



# Tamara J. Moore

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*With a background in mathematics and engineering education, Dr. Tamara J. Moore has research and teaching pursuits situated in the learning and teaching of STEM fields through the integration of these subjects in formal and non-formal learning environments. She believes that providing students with realistic and socially relevant contexts in which to learn STEM content also furthers their interests and motivation in these subjects. Dr. Moore is a recipient of a 2010 NSF CAREER Award and a 2012 Presidential Early Career Award for Scientists and Engineers (PECASE).*

## Defining quality K-12 engineering education |→

Dr. Moore’s research has identified characteristics of a quality engineering education at the undergraduate level—a “Framework for Quality K-12 Engineering Education.” This involved an extensive literature review for K-12 engineering and STEM education, and understanding the ways in which teachers and schools implement engineering and engineering design in their classrooms. The framework is designed to be used as a tool for evaluating the degree to which academic standards, curricula, and teaching practices address the important components of a quality K-12 engineering education. Additionally, this framework can be used to inform the development and structure of future K-12 engineering education standards and initiatives.

## Integrating STEM disciplines in the learning process |→

How does engineering and engineering thinking promote learning in the K-12 classroom, as well as in higher-education engineering classrooms? Dr. Moore defines this area of research as STEM integration – the merging of all or some of the content and practices of science, technology, engineering and mathematics in order to deepen and broaden student understanding of STEM disciplines and increase interest in STEM careers. She examines effective practices in STEM teaching and learning through complex problem solving, inquiry-based learning and cooperative learning.

To investigate STEM integration, Dr. Moore’s research is guided by the rich and engaging learning experiences that foster deep content understanding in STEM disciplines for all students. She examines the need for curricula that integrates STEM contexts for teaching disciplinary content in meaningful ways. There also is a focus on the need for new models of teaching, so instructors can learn disciplinary content using STEM contexts that lead to meaningful learning.

## Effective STEM instructional and learning practices in learning environments |→

Most of Dr. Moore’s funded research projects focus on the creation and implementation of engaging and interactive learning experiences for students through curricular innovation. One example of this research is to build upon and extend the framework for mathematical modeling tasks called Model-Eliciting Activities (MEAs), which are case-based, authentic assessments of real-world contexts (e.g., engineering tasks) that require

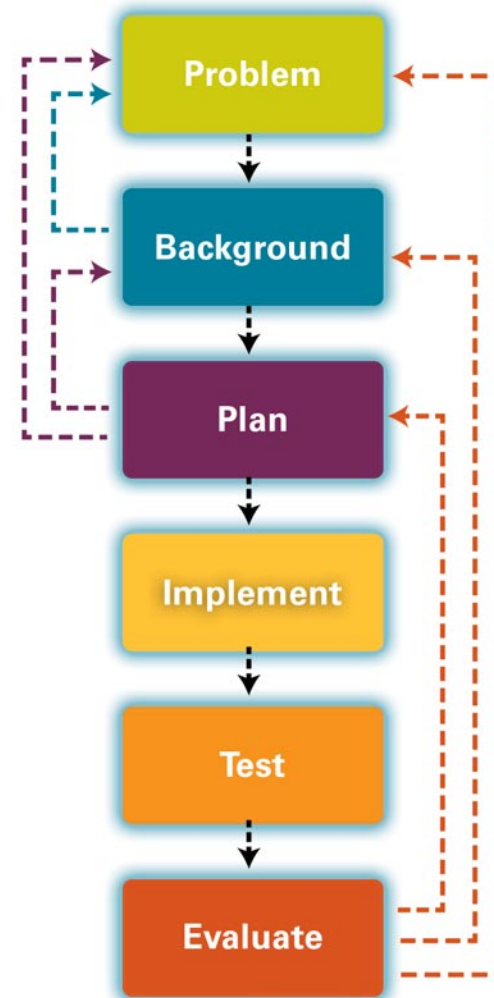


teams of students to come to a solution. Similarly focused research involves the PictureSTEM project. This aims at integrating science, technology and mathematics content instruction in meaningful and significant ways for kindergarten through fifth grades. These instructional modules have the potential to transform the way literacy and STEM are taught at the elementary level.

### Providing quality teacher and professional development programs that use curricular innovations

Understanding student success is dependent on teacher effectiveness, Dr. Moore is working on EngrTEAMS to increase grade 4-8 student learning of science and mathematics concepts. This project is designed to help teachers develop engineering design curricular units for each of the major science topic areas within the Minnesota State Academic Science Standards for use across the United States and beyond. Because the teachers who teach in high-needs schools will develop and implement the curriculum modules, this project will be able to document the learning outcomes of underrepresented populations when presented with curriculum modules.

[FUNDING] NSF MATHEMATICS AND SCIENCE PARTNERSHIP PROGRAM; NSF TRANSFORMING UNDERGRADUATE EDUCATION IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (TUES) PROGRAM; NSF CAREER PROGRAM — ENGINEERING EDUCATION AND CENTERS



**KEY PUBLICATIONS** Moore, T.J., Glancy, A.W., Tank, K.M., Kersten, J.A., Smith, K.A. & Stohlmann, M.S. (2014). A framework for quality K-12 engineering education: Research and development. *Journal of Precollege Engineering Education Research*, 4(1), 1-13. Tank, K.M., Pettis, C., Moore, T.J., & Fehr, A. (2013). Designing animal habitats with kindergartners: Hamsters, picture books, and engineering design. *Science and Children*, 50(9), 59-63. Moore, T.J., Miller, R.L., Lesh, R.A., Stohlmann, M.S., & Kim, Y.R. (2013). Modeling in engineering: The role of representational fluency in students' conceptual understanding. *Journal of Engineering Education*, 102(1), 141-178. Moore, T.J., Guzey, S.S., & Brown, A. (2014). Greenhouse design to increase habitable land: An engineering unit. *Science Scope*, 37(7), 51-57.



## William C. Oakes

- + Professor, School of Engineering Education  
Director, EPICS (Engineering Projects in Community Service)
- + PhD, Mechanical Engineering, Purdue University  
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*Dr. William C. Oakes' roles as a professional engineer, an educator, and the director of Purdue's EPICS (Engineering Projects in Community Service) programs compel a research agenda that encompasses such subjects as human-centered design, interdisciplinary teaming, leadership, ethical reasoning, diversity, retention, and faculty development. A co-recipient of the National Academy of Engineering's Bernard M. Gordon Prize (2005), Dr. Oakes has also received the Thomas Ehrlich Faculty Award for Service Learning (2006), the National Society of Professional Engineers Educational Excellence Award (2004), and the American Society for Engineering Education's Chester F. Carlson Award for Innovation in Engineering Education (2012).*

### Service learning and design in engineering education

↳ EPICS ([www.purdue.edu/epics](http://www.purdue.edu/epics)) is the focus of and often the context for Dr. Oakes' research. EPICS has three components: EPICS Purdue, EPICS University, and EPICS High. EPICS Purdue comprises the EPICS courses that draw first-year students through seniors from across engineering and across campus (70+ majors). Students engage in the design, development, and delivery of projects that address needs within local and global underserved communities. EPICS University, based at Purdue, works with other universities nationally and internationally to implement EPICS programs at those institutions. Curriculum and assessment materials are developed at Purdue and shared across EPICS programs. EPICS High works nationally and internationally to engage high school students in identifying needs within their own communities and developing designs that use technology to meet these needs. Teachers and engineering mentors are trained by EPICS High to guide the student teams. EPICS High is active in 10 states and seven countries and is engaging a substantially more diverse population than traditional pre-engineering programs while meeting needs of local communities. Thousands of students have participated in EPICS programs nationally and internationally, delivering projects to local communities and affecting countless lives. Dr. Oakes' research is focused around themes of understanding and enhancing the impact of the university and pre-university programs on students, faculty/teachers, and communities.

**DESIGN** How do students learn human-centered design? How can we assess this learning? What is the impact of the service-learning context?

**PROFESSIONAL SKILLS** How do students develop professional skills, including cross-disciplinary teaming and leadership, communication, and ethical reasoning? How do we assess these skills? What is the impact of the service-learning context? What is the impact of the cross-disciplinary experience on students within and outside of engineering?

**PROFESSIONAL PREPARATION AND PERSONAL IMPACT** How do service-learning experiences such as EPICS prepare students for their professional careers? What impact do these experiences have on graduates (e.g., their career choices, civic engagement, volunteering)?

**FACULTY AND TEACHER DEVELOPMENT** How can faculty and teachers be equipped and supported to guide diverse EPICS teams, maximizing learning and community impact? How does EPICS impact them, professionally and personally, and their view of engineering?

**ENGINEERING PATHWAYS AND DIVERSITY** How does EPICS impact students' interest, participation, and retention in engineering? What is the impact on populations who have traditionally been underrepresented in engineering?



**GLOBAL AND COMMUNITY PERSPECTIVES** How do local and global experiences develop cultural and social awareness? How do these experiences impact student identity, as a person and a professional? What are the differences in local and global service-learning experiences on participants?

**COMMUNITY IMPACTS** How do these programs impact communities? How does partnership with EPICS influence views of engineering?

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**[FUNDING]** NSF DIVISIONS OF UNDERGRADUATE EDUCATION AND OF ENGINEERING EDUCATION AND CENTERS; CORPORATION FOR NATIONAL AND COMMUNITY SERVICE'S LEARN AND SERVE AMERICA; HEWLETT-PACKARD; MOTOROLA FOUNDATION; NATIONAL INSTRUMENTS; INTEL; MARTINSON FAMILY FOUNDATION

Purdue EPICS students and faculty pose in front of a new home for Habitat for Humanity, along with the proud homeowner and her son. Funded by Ford Motor Company, the home was designed by the EPICS team to have lower energy costs and was built in BioTown USA (Reynolds, Indiana) using sustainable construction practices to reduce cost and environmental impact.

**KEY PUBLICATIONS** Zoltowski, C., Oakes, W. & Cardella, M. (2012). Students' ways of experiencing human-centered design. *Journal of Engineering Education*, 101(1), 28-59. Schaffer, S.P., Chen, X., Zhu, X. & Oakes, W. (2012). Self-efficacy for cross-disciplinary learning in project-based teams. *Journal of Engineering Education*, 101(1), 82-94. Coyle, E.J., Jamieson, L.H. & Oakes, W.C. (2005). EPICS: Engineering Projects in Community Service. *International Journal of Engineering Education*, 21(1), 139-150.





## Matthew W. Ohland

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+ PhD, Civil Engineering, University of Florida

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MS, Mechanical Engineering, Rensselaer Polytechnic Institute

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*Dr. Matthew W. Ohland's research focuses on [1] longitudinal studies of engineering students' persistence and performance and [2] team formation and team skill measurement, both of which enable data-driven decision-making for engineering faculty and administrators. A two-time recipient of the *Journal of Engineering Education's* Wickenden Award for best paper (2009 and 2012) and of the Helen Plants Award for best non-traditional session at the Frontiers in Education conference (2008), Dr. Ohland has made a national impact through his research and his sustained commitment to the development of the field of engineering education.*

### — Student pathways, success, and institutional policy

↳ To study engineering student pathways, Dr. Ohland created the Multiple-Institution Database for Investigating Engineering Longitudinal Development (MIDFIELD), which includes up to 20 years' transcript-level data for nearly one million students at 11 universities—205,980 of them engineering students. Including all undergraduate students in the dataset, not just engineering students, enables important comparisons to understand how students in engineering are different from—and similar to—students in other disciplines and to help institutions identify how various racial and gender groups are performing.

This work has dispelled the long-held belief that engineering has a lower rate of retention than other majors. Retention appears to be low because although more engineering students do persist, those who leave are not replaced because there is little influx into engineering from other disciplines. This finding is changing the conversation around retention in engineering education, pointing to the need to examine recruitment strategies and curricular flexibility to attract more students to engineering before and after they enroll in college.

Further work showed that women enrolling in engineering are as likely to graduate as men. While there is a gender gap, it does not widen during the college years. Dr. Ohland and his research group are also taking a critical look at how success is measured in engineering education, the biases that result when certain measures are used, and the value of using multiple measures. This work is likely to change the standard set of metrics used in measuring the progress of engineering students.

The findings of Dr. Ohland's longitudinal studies of engineering students have affected both policy and practice in engineering colleges, providing important guidance to faculty, administrators, and directors of women in engineering programs and minority engineering programs.

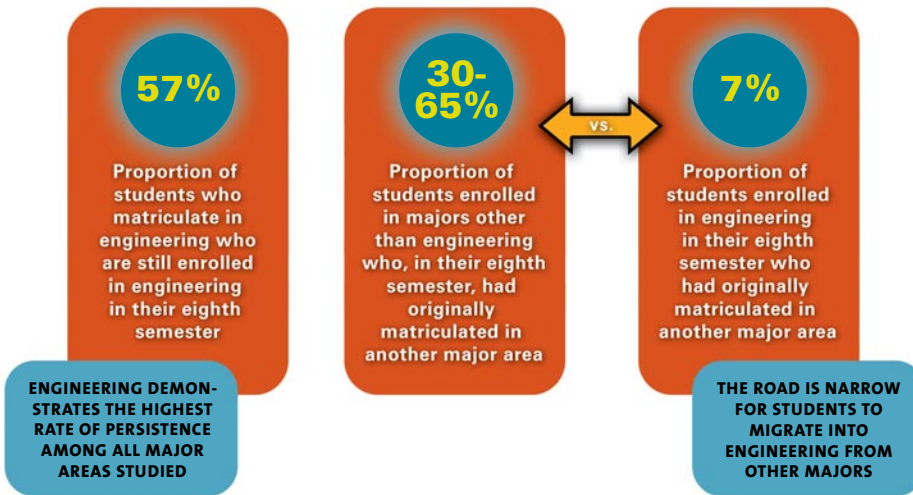
### — Supporting the use of teams in the classroom

↳ Dr. Ohland directed the development of the Comprehensive Assessment of Team-Member Effectiveness (CATME, an instrument and web-based tool for peer evaluation) and the Team-Maker (a web-based system for team formation; see <https://engineering.purdue.edu/CATME> for both).

If faculty assess team effort at all, they commonly use a fixed-allocation, zero-sum-game system—e.g., each member of a team of four has 100 points to allocate, and awarding 25 points to each team member indicates equal effort. Such systems are fraught with inaccuracy: there is social pressure to give equal ratings, and the rating itself focuses on the credit awarded. Other approaches either are too complicated or fail to distinguish the multiple ways that students contribute to team activity. Dr. Ohland's research demonstrated that the use of behavioral anchors is more efficient and effective.

These tools for managing academic teams are used by more than 1,800 faculty and 90,000 students at 400 institutions around the world, and were recognized with the Premier Award for Excellence in Engineering Education Courseware.

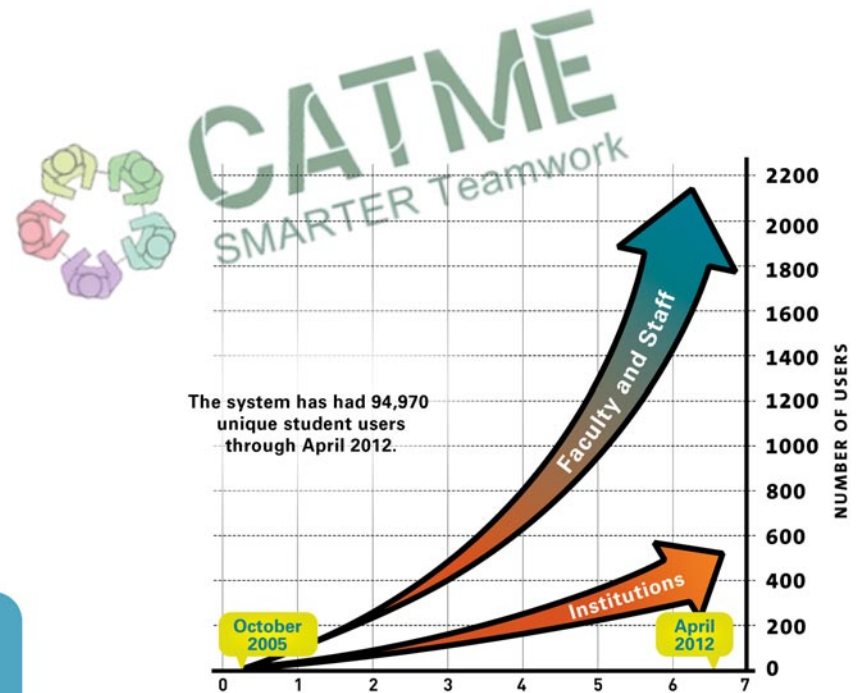
### Selected Key Findings From the MIDFIELD Database



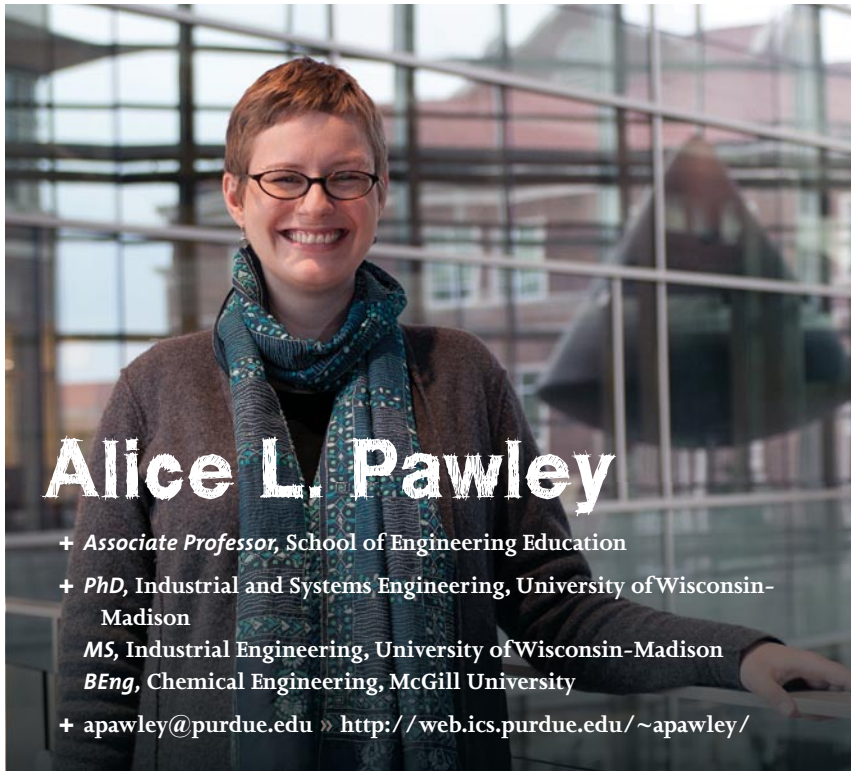
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[FUNDING] NSF DIVISIONS OF ENGINEERING EDUCATION AND CENTERS, UNDERGRADUATE EDUCATION, HUMAN RESOURCE DEVELOPMENT, AND RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS

### Usage of the CATME Tool, 2005-2012



**KEY PUBLICATIONS** Ohland, M.W., Sheppard, S.D., Lichtenstein, G., Chachra, D., Eris, O. & Layton, R.A. (2008). Persistence, engagement, and migration in engineering. *Journal of Engineering Education*, 97(3), 259-278. Ohland, M.W., Brawner, C.E., Camacho, M.M., Long, R.A., Lord, S.M. & Wasburn, M.H. (2011). Race, gender, and measures of success in engineering education. *Journal of Engineering Education*, 100(2), 225-252. Ohland, M.W., Loughry, M.L., Woehr, D.J., Finelli, C.J., Bullard, L.G., Felder, R.M., Layton, R.A., Pomeranz, H.R. & Schmucker, D.G. (in press). The comprehensive assessment of team member effectiveness: Development of a behaviorally anchored rating scale for self and peer evaluation. *Academy of Management: Learning & Education*, [http://aom.pace.edu/InPress/main.asp?action=unassigned&p\\_id=2&p\\_short=AMLE](http://aom.pace.edu/InPress/main.asp?action=unassigned&p_id=2&p_short=AMLE).



# Alice L. Pawley

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**Committed to helping engineering develop as a more socially just profession in a global context, Dr. Alice L. Pawley creates new models for thinking about gender and race in the context of engineering education. A 2010 NSF CAREER Award recipient, she uses novel theoretical and methodological approaches in critical research that explores the persisting underrepresentation in engineering education of white women and of men and women of color. She also pursues research in environmental sustainability education.**

## Diversity in STEM education |→

**AT THE UNDERGRADUATE LEVEL** Over the last three decades, educators in engineering have made massive efforts to increase the numbers of women and people of color in engineering undergraduate programs. While numbers have improved, they have stalled at dispiritingly low levels.

Through her NSF CAREER Award-sponsored research, Dr. Pawley heads a project that asks, How do underrepresented undergraduate engineering students describe their interactions with educational institutions through personal narratives? What institutional factors do these narratives reveal that affect the educational persistence and success of white women and students of color in undergraduate engineering educational institutions?

The narratives will be analyzed both deductively (informed by sociological theories of institutional structure and critical intersectional theories of gender and race) and inductively (deploying feminist and decolonizing methodological strategies and theories) to propose a new theoretical framework of “gendered” and “raced” institutions in the context of engineering education that can be incorporated into researchers’ and practitioners’ ways of understanding “underrepresentation.”

The broader significance and importance of this project will be to provide new insights into the perplexing and persistent problem of low representation of some groups in engineering degree programs and, it is hoped, to inform policy decisions within engineering schools and potentially at other higher education administrative levels as well.

**AT THE FACULTY LEVEL** In other diversity-related research initiatives, Dr. Pawley co-created the Purdue Center for Faculty Success (PCFS), which provides targeted research, programs and university-level coordination to increase the number of minority women in STEM faculty positions, improve the success of all women STEM faculty, and engage all faculty in transforming the institution to be more inclusive of women and people of color.



Dr. Pawley's long-term research goals in this project are to understand the key factors that impact the recruitment and success of women, especially minority women, in STEM faculty positions at Purdue and to inform the implementation of effective institutional policies and procedures that can improve women faculty members' opportunities for academic advancement.

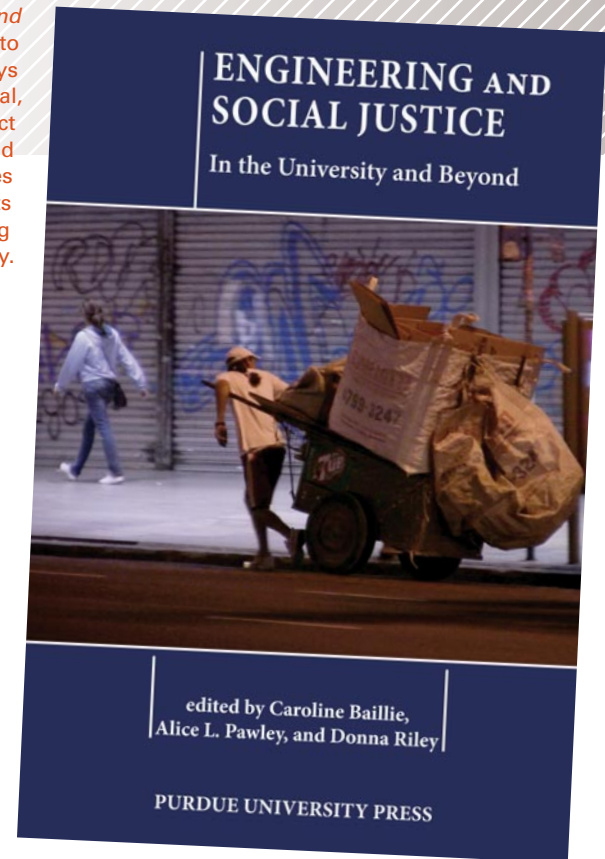
The research team conducts two main studies. The Academic Career Pathways study works to determine the extent to which women's career pathways into and through the academic levels in STEM disciplines at Purdue are modeled by pipeline or chilly climate ideas and vary by ethnicity, and how we might conceive of new studies. The Institutional Ethnography study explores faculty members' lived experiences of two key policies: the promotion and tenure policy that varies by college, and the parental leave policy that started at the same time as the grant. This research uses intersectional theory to look at race and gender together, and initiates institutional change through policy recommendations.

### Assessing sustainability knowledge in undergraduate engineers

→ This research aims to develop a conceptual framework for assessing sustainability knowledge gained by undergraduate engineering students and to explore elements of a sustainability concept inventory. The goal is to help faculty learn how to better prepare students to work as engineers in and for a world impacted by climate change.

[FUNDING] NSF DIVISIONS OF HUMAN RESOURCE DEVELOPMENT AND OF ENGINEERING EDUCATION AND CENTERS

Co-edited by Dr. Pawley, *Engineering and Social Justice: In the University and Beyond* invites scholars to think and teach in new ways that acknowledge the social, as well as technical, impact of engineering on our world and that open possibilities for social justice movements to help shape engineering and technology.



**KEY PUBLICATIONS** Baillie, C., Pawley, A.L., Riley, D. (eds.). *Engineering and social justice: In the university and beyond*, ISBN 978-1557536068. Pawley, A.L. (in press). Engineering faculty drawing the line: A taxonomy of boundary work in engineering schools. *Engineering Studies*. Cardella, M.E., Hoffmann, S.R., Ohland, M.W., Pawley, A.L. (2010). Sustaining sustainable design through "normalized sustainability" in a first-year engineering course. *International Journal for Engineering Education*, 26(2-3).



## Mary K. Pilotte

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*Dr. Mary K. Pilotte describes herself as an “intra-preneurial agent of change” with more than 20 years’ experience in engineering, manufacturing and operations excellence. She has held a variety of industrial leadership roles, including manufacturing plant management, design engineering manager for new product and process development, and director of interdisciplinary integration teams for strategic mergers and acquisitions. Dr. Pilotte’s goal is to have students gain real-life, practical experience in the classroom by solving open-ended problems of industrial concerns, similar to what they may face when working in engineering practice.*

**Industrial research activity** |→ As demographics shift within the industrial work place due to increasing Baby Boomer retirements, the critical concern of engineering knowledge capital retention grows. Dr. Pilotte’s research explores topics around engineering culture, including engineering communication behaviors and norms. In particular, identifying potential areas of difference and/or similarity across aspects of diversity (ethnicity, gender, engineering discipline, industry sector, position title) for practicing engineers within industry. This was a first step in discovering areas of potential to maximize knowledge sharing and transfer within engineering workgroups. In similar research, she focuses on differentiated aspects of the engineering work culture.

**Bringing authentic engineering practices to the classroom** |→ Relative to the School of Engineering Education’s desire to increase industrial contact, Dr. Pilotte is creating engaging student learning through opportunities for “real-life, in-context practice-based problem solving.” Exposing students to the uncertainties and difficulties they will face in their career as an engineer helps them develop the competencies, positive attitude and perseverance to see any engineering problem to completion. She hopes the relationships and data sets cultivated inspire future practice-oriented study extensions, expanded analysis, and opportunities for even greater industrial engagement.

Related to industrial contexts, as faculty of practice, significant effort has been placed on identifying and idealizing industry-based projects that can be scoped and appropriately positioned into First-Year Engineering (FYE) and Multidisciplinary Engineering (MDE) classrooms. In that vein, she is examining sections of Purdue’s FYE courses, to assess students’ perceived value of industry partner contact.

**Communication with industry** |→ Dr. Pilotte understands the importance of sharing information with industry, so that executives may put in place policies that enhance the quality of the engineering profession with and among employees. Likewise, reaching out to industry allows them to give input and become an active stakeholder in engineering education. She produces and distributes “Industry Slicks”—brief documents—that explain her research and why the topic and findings matter to those in the boardroom and how it may improve their operation.



**“I’m interested in engaging industrial firms  
in order to bring real-life, practical  
experience to our students.”**

**KEY PUBLICATIONS** **Pilotte, M. K.**, Bairaktarova, D. & Evangelou, D. (2013). “Trans-discipline engineering communication characteristics and norms: An exploration of communication behaviours within engineering practice”, *Australasian Journal of Engineering Education*, Vol. 19, No. 2, pp. 87-99, <http://dx.doi.org/10.7158/D12-009.2013.19.2>. Streveler, R. A., Smith, K. A., & **Pilotte, M.** (2012). *Aligning Course Content, Assessment, and Delivery: Creating a Context for Outcome-Based Education*. In K. Yusof, N. Azli, A. Kosnin, S. Yusof, & Y. Yusof (Eds.) *Outcome-Based Science, Technology, Engineering, and Mathematics Education: Innovative Practices* (pp. 1-26). Hershey, PA: Information Science Reference. doi:10.4018/978-1-4666-1809-1.ch001 **Pilotte, M.** and Evangelou, D. (2012). “Building Bridges - Identifying Generational Communication Characteristics to Facilitate Engineering Collaboration and Knowledge Transfer Across Field-Practicing Engineers.” *Engineering Studies*, 4(1), 79-99. doi: 10.1080/19378629.2011.653976. **Pilotte, M.**, Kovaichelvan, V., Chand, S., and Lyer, A. (2012). *Global Experiential Projects with a Manufacturer in India: Insights from Five Years of Experience*. *INFORMS Transactions on Education*, 13(1), 31-43.





## Şenay Purzer

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*Through her 2012 NSF CAREER Award research and other initiatives, Dr. Şenay Purzer explores the assessment and measurement of difficult engineering constructs, such as innovative thinking, problem-solving, decision-making, and design. In her lab, the Engineering Learning Observatory, she employs video and discourse analysis methods to describe and quantify the thinking processes of learners and the complex nature of social and cognitive factors that impact student learning and skill development.*

**Assessing innovation and creativity** |→ This much-needed and urgent area of research—the subject of Dr. Purzer’s NSF CAREER Award—has broad impact for the education of engineering students and the economic development of societies.

Engineers are expected to produce better, more efficient, and more affordable designs than the designs of previous generations. This project seeks to develop ways to measure the innovation skills of engineering students and use these findings to design engineering degree programs that produce more innovative graduates.

Dr. Purzer is [1] investigating how engineering students define innovation, understand the innovation process, and engage in innovation; [2] developing an understanding of possible gender and cultural differences in students’ approaches to innovation; [3] defining innovation in light of literature and research findings; and [4] developing assessments for classroom use in both college and pre-college settings.

**Assessing teamwork, argumentation, and collaborative decision-making** |→ Engineering is a social activity. Hence, the study of discourse, collaboration, and argumentation is an essential component of engineering education research. In her dissertation, Dr. Purzer investigated a first-year design classroom and the relationship between team interactions and individual student learning. In this project, she employed mixed-method approaches to gain a deep understanding of an engineering design classroom environment, using hours of video-recorded student discussions and classroom activities.

Her recent projects examine argumentation among engineering students and the relationship between team collaboration methods and the quality of collaborative decisions.

**Assessing critical thinking and information literacy skills** |→ Skills, tools, and methods used in engineering are constantly changing and evolving. Engineering students thus have to seek information and resources beyond what they gain through coursework on their own. Dr. Purzer’s research in the assessment of critical thinking and information literacy skills led to the

development of several research and classroom assessment instruments such as the Self-Assessment of Problem Solving Strategies (SAPSS) and Critical Engineering Literacy Test (CELT). Work in this area promises to inform teaching and enhance learning for undergraduate and graduate students.

**Preschool-12 engineering education** |→ Improving pre-school-12 (pre-college) engineering education is critical to recruiting more diverse and more able engineering students. As director of the INSPIRE Assessment Center (INSPIRE is Purdue's Institute for P-12 Engineering Research and Learning), Dr. Purzer develops assessment tools, including creativity assessments for design projects used in elementary classrooms.

She also leads an initiative, the "INSPIRE Assessment Center for STEM Literacy" project, that aims to widen and ease the dissemination of valid and reliable assessment instruments for measuring various constructs related to pre-college engineering. Through these and other efforts, the center serves as a platform for collaboration and supports the growing community of pre-college engineering education researchers, outreach developers, and P-12 teachers. Dr. Purzer is also working closely with Purdue's Women in Engineering Program to enhance program evaluation techniques.

Along with her involvement in INSPIRE, Dr. Purzer is a STEM faculty coordinator on a large-scale, multi-year NSF Math Science Targeted Partnership grant (Science Learning through Engineering Design, or SLED) that examines the purposeful integration of engineering design-based instruction in the elementary school (grades 3-6)

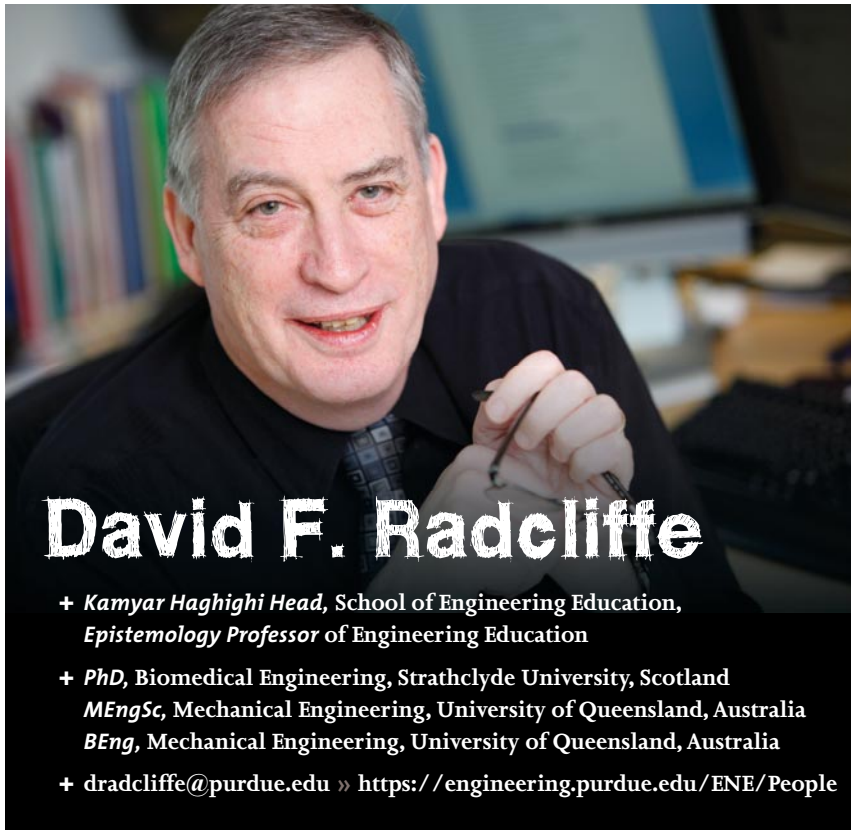
setting. One discovery activity in this project is the development of grade-appropriate, standards- and engineering design-based science lessons for grade 3-6 students.

[FUNDING] NSF DIVISION OF ENGINEERING EDUCATION AND CENTERS

In the Engineering Learning Observatory, Dr. Purzer and her research team investigate learners' thinking processes and the ways in which social and cognitive factors affect student learning.



**KEY PUBLICATIONS** Yaşar, Ş., Baker, D., Robinson-Kurpius, S., Krause, S. & Roberts, C. (2006). Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology. *Journal of Engineering Education*, 95(3), 205-216. Purzer, Ş. (2011). The relationship between team discourse, self-efficacy, and individual achievement: A sequential mixed-methods study. *Journal of Engineering Education*, 100(4), 655-679. Wertz, R.E.H., Fosmire, M.J., Purzer, Ş. & Cardella, M.E. (under review). Assessing information literacy skills demonstrated in an engineering design task. *Journal of Engineering Education*.



## David F. Radcliffe

- + *Kamyar Haghighi* Head, School of Engineering Education, Epistemology Professor of Engineering Education
- + *PhD*, Biomedical Engineering, Strathclyde University, Scotland  
*MEngSc*, Mechanical Engineering, University of Queensland, Australia  
*BEng*, Mechanical Engineering, University of Queensland, Australia
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*A boundary agent and synthesizer of ideas*, Dr. David F. Radcliffe is an internationally recognized leader in engineering education transformation based on research and scholarship who has made important contributions to engineering education reform in Australia and the U.S. For nearly 30 years, he has conducted research on engineering design, engineering education innovation, engineering education systems, and learning environments through creating strategic, interdisciplinary partnerships between engineers and social scientists. He initiated the Australian Virtual Engineering Library, which morphed into the Sustainability Knowledge Network; was the inaugural national Teaching Fellow in Australia (1994); and is a past president of the Australasian Association for Engineering Education (2005).

**Engineering design and practice research** |→ Intrigued by the related questions of *What is the nature of engineering practice, in particular engineering design?* and *What does it take to prepare for it?*, Dr. Radcliffe initiated two interdisciplinary research groups to study engineers *in situ*. These groups, the Engineering Practice Research Group and later the Catalyst Research Centre for Society and Technology, comprised researchers from engineering design, industrial anthropology, learning sciences, and information sciences. The research involved the development of a new sociotechnical research framework that drew upon diverse research methodologies and methods (including ethnography and phenomenography) to study engineering teams in their daily practice by researchers embedded in the workplace, often for extended periods. Much of this research was conducted as part of a series of strategic learning partnerships with engineering firms across aerospace, construction, and mining industries in Australia as well as new product development in SMEs (small and medium enterprises) and rehabilitation engineering in clinical settings. The current focus of this work is on professional competencies and engineering epistemologies.

**Engineering education systems and communities** |→ Dr. Radcliffe also undertakes research and policy development and implementation focused on engineering education transformation. This began when he prepared the first draft of “Changing the Culture: Engineering Education into the Future,” the report that changed the accreditation of the engineering programs in Australia in the 1990s into outcomes-based assessment. The motivating question is, *How can we bring about systemic change in lifelong engineering education sufficient to meet the emerging challenges facing societies globally?*

Dr. Radcliffe created the Advanced Engineering Capability Network in Australia to identify success factors for industry-education-community partnerships and developed the Capability Strategy Matrix (CSM) as an analytical framework to explore the many different types of capacity-building programs by aligning educational initiatives in K-12 with university engineering programs and a wide variety of continuing professional development initiatives. Current research explores the transition of the engineering education research community from loose networks of relatively isolated scholars to the formation of academic units.



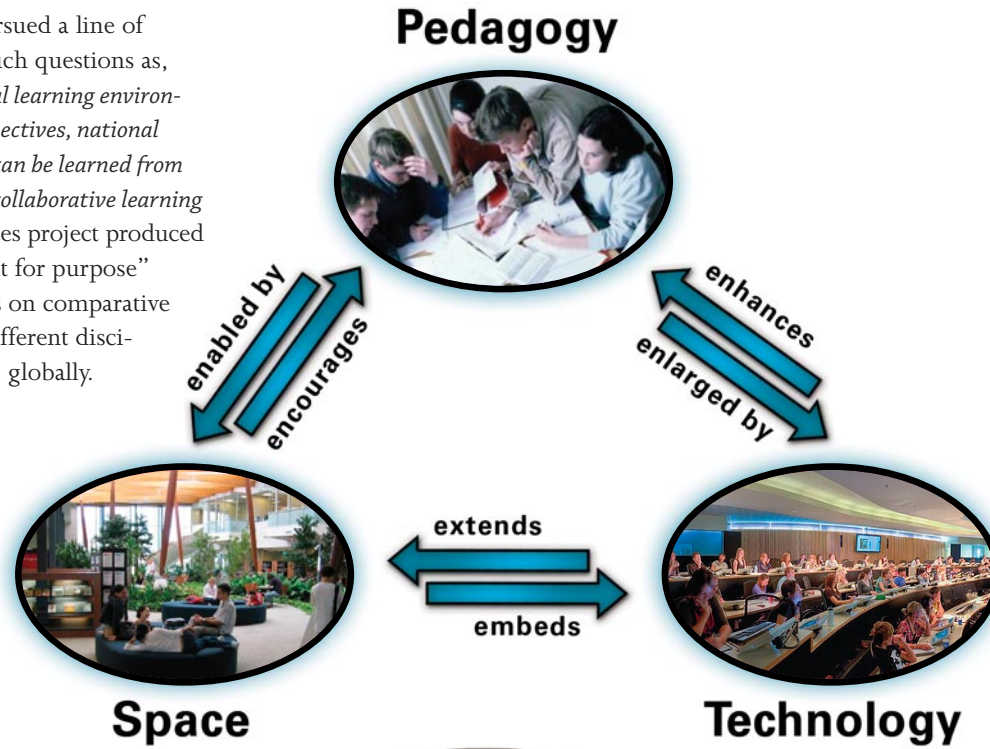


**Learning environments** |→ Dr. Radcliffe has pursued a line of research and innovation over the past 15 years driven by such questions as, *How does the design of formal and informal, physical and virtual learning environments influence pedagogy? How do cultural and historical perspectives, national and disciplinary, influence the design of learning places? What can be learned from innovative design and engineering workplaces for the design of collaborative learning places?* The interdisciplinary Next-Generation Learning Spaces project produced the Pedagogy-Space-Technology framework for creating “fit for purpose” learning environments. The current focus of this research is on comparative analysis of the development of learning environments in different disciplines and different national settings and cultural traditions globally.

**Engineering futures** |→ These research themes are part of a broader scholarly interest in understanding the major eras of engineering education past and present in relation to trends in industry and engineering practice over the past century or so. This historical perspective sheds light on how we can educate engineers to meet pressing global challenges—climate change, water, energy, food, housing, transport, urbanization, sustainability—in the context of major geopolitical and demographic shifts.

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**[FUNDING]** NSF OFFICE OF CYBERINFRASTRUCTURE; AUSTRALIAN RESEARCH COUNCIL; CARRICK INSTITUTE; INDUSTRY



We need to re-imagine how we form engineers... Can we create agile, innovative systems of education that are learner-centered, evidence-based, grounded locally yet global in outlook by integrating the best of practice-oriented education with knowledge from the engineering and Learning sciences?



**KEY PUBLICATIONS** Radcliffe, D.F., Wilson, H., Powell, D. & Tibbetts, B. *Learning spaces in higher education*, ISBN 978-1-86499-943-3. Radcliffe, D.F. *Collaborative strategies for building advanced engineering capability*, ISBN 978-1-64999-929-7. Walther, J., Kellam, N., Sochacka, N. & Radcliffe, D.F. (2011). Engineering competence? An interpretive investigation of engineering students' professional formation. *Journal of Engineering Education*, 100(4), 703–740.



## Karl A. Smith

- + *Cooperative Learning Professor of Engineering Education, School of Engineering Education*  
*Professor Emeritus of Civil Engineering and Morse-Alumni Distinguished Teaching Professor Emeritus, University of Minnesota*
- + *PhD, Educational Psychology, University of Minnesota*  
*MS, Metallurgical Engineering, Michigan Technological University*  
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*A prominent and pioneering leader in engineering education research, Dr. Karl A. Smith pursues interests in building research capabilities in engineering education; faculty and graduate student professional development; the role of cooperation in learning and design; problem formulation, modeling, and knowledge engineering; and project and knowledge management and leadership. A 2001 recipient of the American Society for Engineering Education's Chester F. Carlson Award for Innovation in Engineering Education, Dr. Smith serves on the national advisory boards for the NSF-CLT Center for the Integration of Research, Teaching, and Learning and the National Academy of Engineering's Center for the Advancement of Scholarship on Engineering Education.*

### **Discipline-based education research and innovation**

↳ Dr. Smith is participating in the National Research Council's consensus study on discipline-based education research (DBER), one of two experts invited to represent engineering in an initiative that also encompasses physics, biology, the geosciences, chemistry, and astronomy. DBER combines knowledge of teaching and learning with deep knowledge of discipline-specific science content, and describes the discipline-specific difficulties learners face and the specialized intellectual and instructional resources that can facilitate student understanding.

Dr. Smith and colleagues have synthesized empirical research on undergraduate teaching and learning in the STEM disciplines; explored the extent to which that research currently influences undergraduate instruction; and identified the intellectual and material resources required to further develop DBER. Post-secondary institutions will be able to use the resulting report—which marks a major step in advancing the disciplinary-based education research agenda—for guidance in instruction and assessment to improve student learning, in bringing greater attention to student mastery (or conceptual understanding) and attrition issues that are related to quality of instruction, and in increasing interest and research activity in DBER.

### **National capacity building in engineering education research and innovation**

↳ As a member of the planning committee for the National Academy of Engineering's Frontiers of Engineering Education (FOEE) symposium, Dr. Smith has helped design and implement a program for emerging engineering education leaders that broadens collaboration, facilitates learning, and promotes the dissemination of pioneering practices in engineering education. Selected participants strengthen their professional capacity for innovation at FOEE by identifying and understanding how to apply identified best practices in engineering education; developing new ideas to advance their innovations in engineering education; developing an understanding that engineering educational innovation should be guided by the evolving evidence-based body of knowledge on engineering learning; establishing long-lasting professional relationships with those attending the symposiums, and through those relationships establishing new or broadened networks with other educational innovators; and becoming agents of change to help advance the U.S. capacity for engineering education innovation.

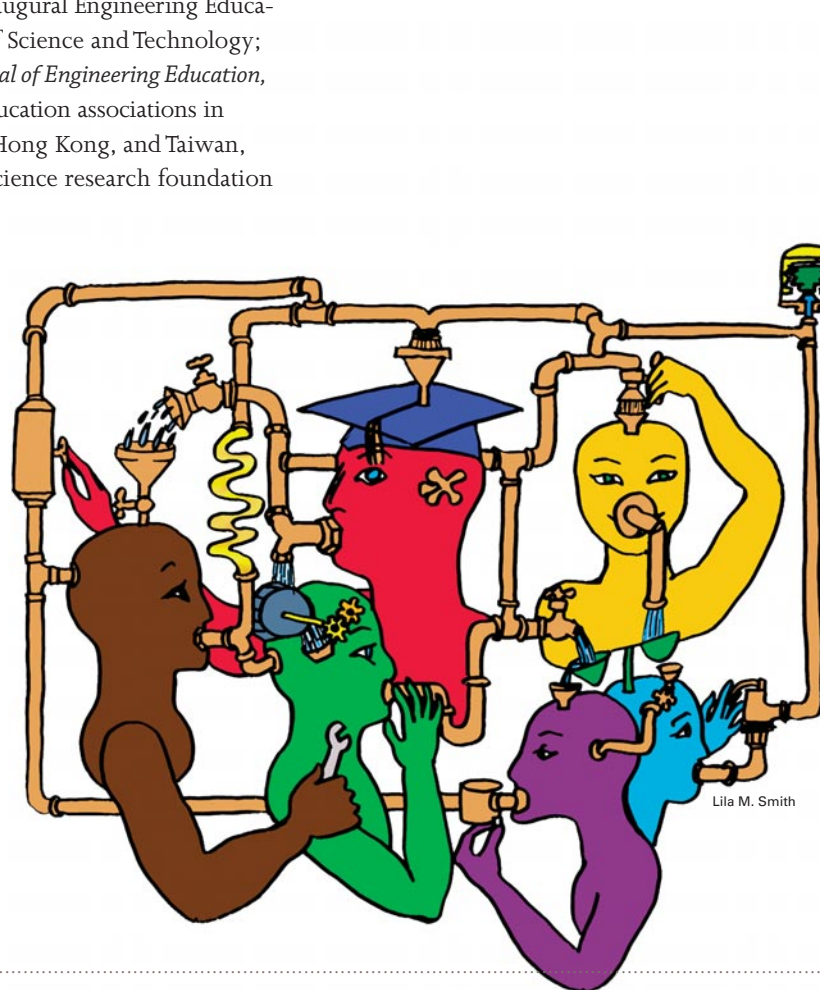
## International capacity building in engineering education research and innovation

→ Dr. Smith has collaborated on emerging engineering education research and innovation initiatives around the world, including helping to create a doctoral program in engineering education at the Universiti Teknologi Malaysia; serving as the inaugural Engineering Education Innovation Fellow at the Hong Kong University of Science and Technology; and, with colleagues and in partnership with the *Journal of Engineering Education*, leading workshops in connection with engineering education associations in Mexico, Latin America, South Africa, India, Malaysia, Hong Kong, and Taiwan, as well as the U.S. These workshops provide a social science research foundation for disciplinary engineering faculty interested in conducting engineering education research and incorporating it into their research portfolio, using a “levels of inquiry” framework to characterize an engineering educator’s progression from a teacher who teaches as taught to one who engages in scholarship to improve performance to some who conduct funded research with graduate students. A systematic study of workshop participants indicates that they generally receive funding at a higher rate and are more successful in getting their research published in archival journals than non-participants.

Extending the engineering education research community further, Dr. Smith has collaborated on the CLEERhub (Collaboratory for Engineering Education Research) web site and offered networking sessions at the annual conferences of the American Society for Engineering Education and Frontiers in Education.

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[FUNDING] NSF DIVISIONS OF ENGINEERING EDUCATION AND CENTERS AND OF UNDERGRADUATE EDUCATION



Lila M. Smith

Dr. Smith’s emphasis on rigorous research—like that supporting a paradigm shift from teacher-centric teaching to student-centric learning—underlies his work in building the engineering education research community.

**KEY PUBLICATIONS** Smith, K.A., Sheppard, S.D., Johnson, D.W. & Johnson, R.T. (2005). Pedagogies of engagement: Classroom-based practices (cooperative learning and problem-based learning). *Journal of Engineering Education*, 94(1), 87-102. Smith, K.A. (2010). Social basis of learning: From small-group learning to learning communities. *New Directions for Teaching and Learning*, 123, 11-22. Smith, K.A. *Teamwork and project management*, ISBN 978-0073103679.





## Ruth A. Streveler

+ Associate Professor, School of Engineering Education

+ PhD, Educational Psychology, University of Hawaii (Manoa)  
MS, Zoology, The Ohio State University  
BA, Biology, Indiana University

+ streveler@purdue.edu » <http://web.ics.purdue.edu/~rastreve/>

**A thought leader and agent of change, Dr. Ruth A. Streveler has achieved national recognition in employing the theories and methods of cognitive psychology to build knowledge in both engineering and the learning sciences, and in helping to build research capacity in the field of engineering education. She is a two-time recipient of the Helen Plants Award for best non-traditional session at the Frontiers in Education annual conference.**

### Difficult concepts in science and engineering |→

What concepts are difficult for students to learn? How do you measure students' conceptual understanding? Why are some concepts so difficult to learn? How do you construct learning environments that help students learn these concepts?

These questions motivate Dr. Streveler's body of research on conceptual change and student misconceptions in engineering, which aims to bring about better learning and teaching of important STEM concepts. Partnering with faculty across the engineering disciplines, she has, in three NSF-funded projects, applied the first question (*Which concepts are difficult for students to learn?*) to transport and thermal science, engineering mechanics and electric circuits, and optical engineering. This work pioneered the use of Delphi studies to collect expert judgment about difficult and important concepts, thereby making a significant methodological contribution to the field.

Her creation, with Dr. Ron Miller, of the Thermal and Transport Science Concept Inventory, or TTCI (<http://www.thermalinventory.com/results.html>), extends the research to address the *measurement of student understanding* in thermal and transport science specifically. Typically multiple-choice tests designed to evaluate a student's working knowledge of fundamental concepts in a given discipline, concept inventories provide a better understanding and assessment of student learning. Administered thus far to more than 1,000 engineering students, the TTCI—an exemplar of concept inventory development—is undergoing further development to increase its diagnostic capabilities and is serving as a test case for developing a larger research and validation methodology that will be extended to other concept inventories.

Streveler's exploration of *why certain concepts are difficult to learn*, and *what kinds of environments are effective in helping students learn them*, bridges the gap between cognitive psychology and engineering education research. In further work, she looks at nanotechnology (e.g., microfluidics, biotechnology, genetic engineering, nanoscale machines), in which fundamental processes are characterized by small-scale dynamic systems, and extends the work of Dr. Michelene Chi and colleagues, who conclude that poor conceptual understanding results from fundamental misconceptions about how small-scale processes differ from the observable, macroscopic behavior that we experience in our everyday lives.

Dr. Streveler tests this theory by creating training protocols and materials that help students create appropriate mental models of fundamentally important dynamic processes (such as the random motion of molecules, atoms, or sub-atomic particles).

Future work will focus on building cross-disciplinary theories or frameworks that broadly characterize *patterns in conceptual understanding*. These theories will help researchers and instructors interpret and apply conceptual understanding research to the creation of effective teaching practices and assessment tools.

### Helping engineering faculty learn to conduct engineering education research

Starting with this essential question—*What can be done to prepare engineering education researchers to shift their focus from teaching and curriculum development to exploring fundamental questions about engineering learning?*—Dr. Streveler aims to increase engineering education research capacity that, in turn, will generate the foundational knowledge needed to fuel evidence-based curriculum reform.

She investigates and compares the epistemological, methodological, and ethical differences embedded in engineering and in engineering education and shares her findings through publications and in workshops (“What Is Rigorous Research in Engineering Education?”, “How People Learn Engineering,” etc.) that have reached more than 500 faculty on three continents (North America, Africa, and Asia).

Using Purdue’s nanoHUB technology, her group is also fostering a virtual worldwide community of engineering and engineering technology education researchers through CLEERhub.org. CLEERhub (Collaboratory for Engineering Education Research) is a digital habitat that functions as a knowledge base, a collaboration space, and a learning environment.

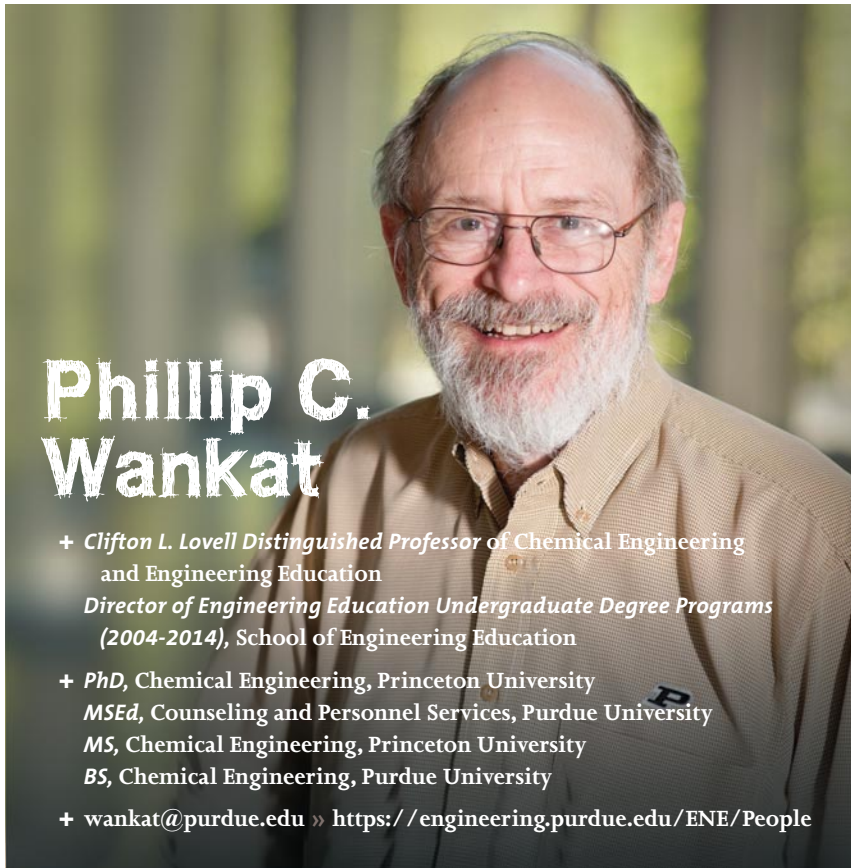
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**[FUNDING]** NSF DIVISIONS OF UNDERGRADUATE EDUCATION; OF ELEMENTARY, SECONDARY, AND INFORMAL EDUCATION; OF RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS; OF ENGINEERING EDUCATION AND CENTERS; AND OF HUMAN RESOURCE DEVELOPMENT



Dr. Streveler’s work in building research capacity in engineering education includes fostering a virtual community of researchers through CLEERhub.org.

**KEY PUBLICATIONS** Streveler, R.A., Litzinger, T.A., Miller, R.L. & Steif, P.S. (2008). Learning conceptual knowledge in engineering: Overview and future research directions. *Journal of Engineering Education*, 97(3), 279-294. Streveler, R.A., Miller, R.L., Santiago Roman, A.I., Nelson, M.A., Geist, M.R. & Olds, B.M. (2011). Using the “assessment triangle” as a framework for developing concept inventories: A case study using the thermal and transport concept inventory. *International Journal of Engineering Education*, 27(5), 1-17. Borrego, M., Streveler, R.A., Miller, R.L. & Smith, K.A. (2008). A new paradigm for a new field: Communicating representations of engineering education research. *Journal of Engineering Education*, 97(2), 147-162.



**Combining expertise in chemical engineering and educational theory, Dr. Phillip C. Wankat is a national leader in developing research-based methods to teach graduate students and new professors how to teach and in developing methods to improve the efficiency and effectiveness of faculty. Named a Walter L. Robb Engineering Education Senior Fellow by the National Academy of Engineering, he also received the Catalyst Award (1993) for teaching from the Chemical Manufacturers Association and both the Chester F. Carlson Award for Innovation in Engineering Education (1990) and the Lifetime Achievement in Chemical Engineering Pedagogical Scholarship Award (2004) from the American Society for Engineering Education.**

**Improving teaching** |→ Dr. Wankat has had a tremendous impact in teaching engineering professors and future professors how to teach. With Dr. Frank Oreovicz, he developed “Educational Methods for Engineers” in the 1980s, a graduate course taught at Purdue and geared toward PhD candidates interested in academic careers. An NSF-funded outgrowth of that effort, their book *Teaching Engineering* (1993) marks the first comprehensive text on the subject, one that—pre-dating the emergence of the formal discipline of engineering education—borrowed from the fields of education and educational psychology for its theoretical perspective. The book opens with specific, practical teaching applications and then offers chapters on psychological types and learning, models of cognitive development, learning theories, and the evaluation of teaching. In the 1990s, *Teaching Engineering* was the second-most-cited publication in the *Journal of Engineering Education*. (It is currently available online, free, at <https://engineering.purdue.edu/ChE/AboutUs/Publications/TeachingEng/index.html>.)

Dr. Wankat’s second book on teaching, *The Effective, Efficient Professor* (2001), also contains research-informed material on improving one’s teaching, along with sections on time management, conducting scholarship and research, and engaging in service.

**Trends in engineering education** |→ Across a range of activities, Dr. Wankat provides a historical perspective on the field of engineering education and contributes to current analyses of the structure of research in the field. What is being published, and by whom? What becomes of the research findings?

With co-authors Drs. Jeffrey Froyd and Karl Smith, Dr. Wankat presents in the paper “Five Major Shifts in 100 Years of Engineering Education” (written for *Proceedings of the IEEE*) an examination of the factors and influences that have reshaped, or are currently reshaping, engineering education, up through the current emphasis on design, learning, and social-behavioral sciences research and the role of technology.

Concurrently with that project, Dr. Wankat has contributed assorted editorials in 2011 and 2012 on the cross-fertilization of engineering education R&D, exploring



the extent of knowledge diffusion in engineering education across the traditional engineering disciplines and finding disciplinary silos in place, within which (but, typically, not beyond which) engineering education findings have impact. Journals publishing these editorials include *Chemical Engineering Education*, 45(4), *IEEE Transactions on Education*, 54(4), *Journal of Professional Issues in Engineering Education and Practice* (in press), and *Journal of STEM Education*, 12(5&6).

As a consultant on Dr. Krishna Madhavan and colleagues' iKNEER project (Interactive Knowledge Networks for Engineering Education Research), Dr. Wankat also contributes to our understanding of the engineering education research space in work that uses interactive knowledge networks and topic modeling techniques to identify researchers' networks and collaborations. The goal: to provide members of the engineering education research community with tools and infrastructure that allow them to understand the structure and networks of knowledge within the community at any given time.

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**[FUNDING]** NSF DIVISION OF ENGINEERING EDUCATION AND CENTERS

***Teaching Engineering* (1993), the first comprehensive text on the subject, borrowed from the fields of education and educational psychology for its theoretical perspective.**



**KEY PUBLICATIONS** Wankat, P.C. & Oreovicz, F.S. *Teaching engineering*, ISBN 978-0070681545. Wankat, P.C. *The effective, efficient professor: Teaching, scholarship and service*, ISBN 978-0205337118. Floyd, J.E., Wankat, P.C. & Smith, K.A. (2012). Five major shifts in 100 years of engineering education. *Proceedings of the IEEE, Special Centennial Issue (100)*.

# INSPIRE *Institute for P-12 Engineering Research and Learning*

+ [www.purdue.edu/INSPIRE](http://www.purdue.edu/INSPIRE)

INSPIRE, the School of Engineering Education's Institute for P-12 Engineering Research and Learning, is at the forefront of what it means to do, learn, and teach engineering at the earliest stages of learning through the high school years.

INSPIRE conducts basic and applied multidisciplinary research on teacher professional development, assessment, student learning, and informal learning, using its research findings to inform the design of engineering curricula, assessment instruments, teacher education, and STEM education policy within the full spectrum of P-12 (preschool through high school) engineering education.

The institute has partnerships with such nationally recognized educational programs as Engineering Projects in Community Service (EPICS), PBS TeacherLine, and the STEM Education Coalition. It hosted the inaugural P-12 Engineering and Design Education Research Summit in 2010 and launched the *Journal of Pre-College Engineering Education Research (J-PEER)* in 2011. INSPIRE also has offered teacher-professional-development programs for P-12 educators, impacting more than 850 teachers and 20,000 students.

## SELECTED RESEARCH PROJECTS

- + *NSF DRK-12: R&D: Quality cyber-enabled engineering education professional development to support teacher change and student achievement (E2PD)*
- + *NSF GSE/RES: Examining engineering perceptions, aspirations, and identity among P-6 girls*
- + *NSF MSP: Using engineering design principles to affect how science and math are taught, this project reaches 200 teachers and 5,000 students across four Indiana school districts.*
- + *NSF CAREER: A study of how engineering students approach innovation*
- + *NSF GSE-RES: Gender research on adult-child discussion in informal engineering environments*



Institute for P-12  
Engineering Research and Learning

INSPIRE was established in 2006 through the generous support of the Stephen D. Bechtel, Jr. Foundation, which also provided sustaining funding for the first five years of the institute.



# The Graduate Program *of the School of Engineering Education*

+ [www.purdue.edu/ENE/Academics/Graduate](http://www.purdue.edu/ENE/Academics/Graduate)

In Purdue's School of Engineering Education, an enthusiastic and committed community of scholars provides ongoing national leadership in building the discipline's intellectual framework. Faculty and graduate students work collaboratively across the entire educational continuum (preschool through college, extending into the workplace) to develop a research base for guiding the preparation of tomorrow's engineers. Living laboratories for conducting research include Purdue's First-Year Engineering Program, Interdisciplinary/Multidisciplinary Engineering Program, Institute for P-12 Engineering Research and Learning (INSPIRE), and Engineering Projects in Community Service program (EPICS). A new program, the Strategic Knowledge Institute, is coming online as a collaboration with industry partners to explore ways to harness the expertise of practicing engineers in diverse work settings.

In the School of Engineering Education's graduate program, each student creates a developmental portfolio that demonstrates how he or she meets 10 competencies that characterize what it means to be an engineering education professional ([www.purdue.edu/ENE/Academics/Graduate/Doctorate/competencies](http://www.purdue.edu/ENE/Academics/Graduate/Doctorate/competencies)):

- + *Synthesize knowledge*
- + *Create knowledge*
- + *Communicate knowledge*
- + *Think critically and reflectively*
- + *Apply engineering education principles to the solution of instructional or curricular problems*
- + *Demonstrate engineering skills*
- + *Engage in professional development*
- + *Participate actively in professional community*
- + *Explain and critique education policy*
- + *Teach engineering*

The graduate program provides a multitude of opportunities to develop these competencies that fit with your personal, professional, and academic goals and that help you develop as an educated citizen and agent of change. Your portfolio is the place to integrate what you learn in the program with the experiences, knowledge, and abilities that you bring with you into the program. In the course of achieving these competencies, you define who you are as an engineering education professional. Alumni of the graduate program have found successful careers in university and P-12 settings as well as in government and international policy, and are finding ways to connect with NGOs, international aid agencies, and professional organizations.





# School of Engineering Education: Past, Present & Future

- 1953** — The Department of Freshman Engineering, the first program of its kind in the country, is established to prepare entering Purdue engineering students for their discipline of choice.
- 1958** — The Department of Freshman Engineering creates Purdue's first honors program, for academically advanced engineering students.
- 1969** — The nation's first Women in Engineering Program is founded in the Department of Freshman Engineering.
- 1969** — The Interdisciplinary Engineering Program is created.
- 1974** — The Minority Engineering Program is founded in the Department of Freshman Engineering.
- 1975** — The National Society of Black Engineers is founded at Purdue.
- 2004** — The School of Engineering Education is established, the first of its kind in the nation. The school brings together the First-Year Engineering Program (formerly the Department of Freshman Engineering), Interdisciplinary/Multidisciplinary Engineering Program, and a new graduate program in engineering education.
- 2006** — The first PhD is granted in the field of engineering education.
- 2006** — INSPIRE (Institute for P-12 Engineering Research and Learning) is founded in the School of Engineering Education.
- 2008** — The Ideas to Innovation Learning Laboratory opens, engaging first-year students in the engineering design process.
- 2009** — The Kamyar Haghighi Headship of Engineering Education is endowed.
- 2010** — The Dale and Suzi Gallagher Professorship in Engineering Education is endowed.
- 2012** — The Crowley Family Professorship in Engineering Education is endowed.
- 2014** — The School of Engineering Education marks its first decade.

# School of Engineering Education: Strategic Plan

**Our Vision** |→ **A MORE INCLUSIVE, SOCIALLY CONNECTED,  
AND SCHOLARLY ENGINEERING EDUCATION**

**Our Mission** |→ **TRANSFORMING ENGINEERING  
EDUCATION BASED ON SCHOLARSHIP AND RESEARCH**

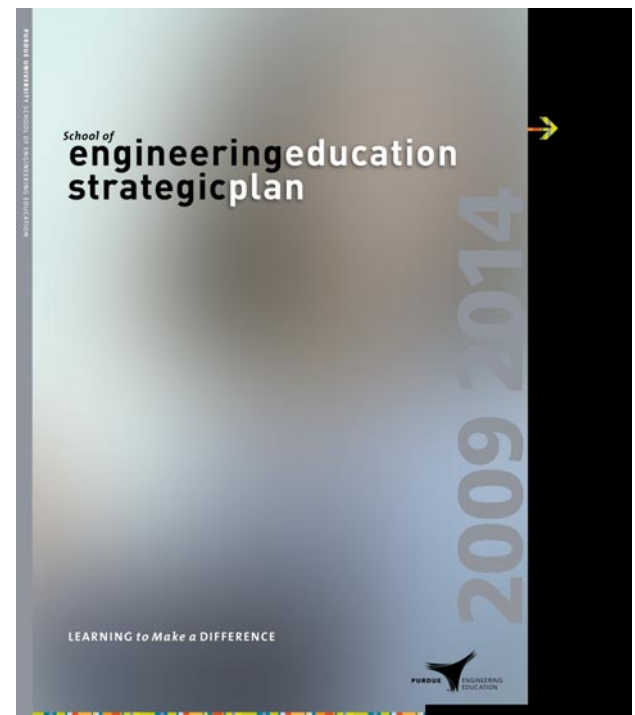
**Our Goals** |→

**EMPOWER OUR PEOPLE:** Empower all members of the School each to contribute to the success of our integrated, multifaceted mission while achieving their individual professional goals.

**SET THE PACE:** Offer a full suite of undergraduate and graduate programs that set the global standard in engineering education grounded in and contributing to cutting-edge scholarship and research.

**TACKLE THE BIG (RESEARCH) QUESTIONS:** Create a world-renowned interdisciplinary research concentration at Purdue that addresses the big questions and challenges facing STEM education, with particular emphasis on engineering.

**GROW THE COMMUNITY:** Identify and build global partnerships and collaborations to elevate our research capabilities and those of the wider engineering education community, while simultaneously facilitating the sharing of experiences across the global community of engineering education scholars.





# ONEVISION THREEPROGRAMS

First-Year Engineering  
Interdisciplinary/Multidisciplinary Engineering  
Graduate Program in Engineering Education

How do we prepare graduate students for careers in academia and industry? Monica F. Cox

How can authentic problems be effectively used to support student learning across multiple learning objectives?  
Heidi Diefes-Dux

How can we design a learning environment that is personalized to individual students?  
Kishor Matham

How do engineering students learn to think with models?  
Sean Murphy

How does engineering thinking develop in informal learning environments?  
Maic Carr

How do we define "engineering" influence who becomes (or doesn't become) an engineer?  
Alice Pauling

How do we learn to work with environments?

How do we learn to work with environments?