Building Engineering Education Research Capacity

Chronicles of a New Center at MSU

Brock J. LaMeres
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(presenting)

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Associate Professor, Chemical & Biological Engineering

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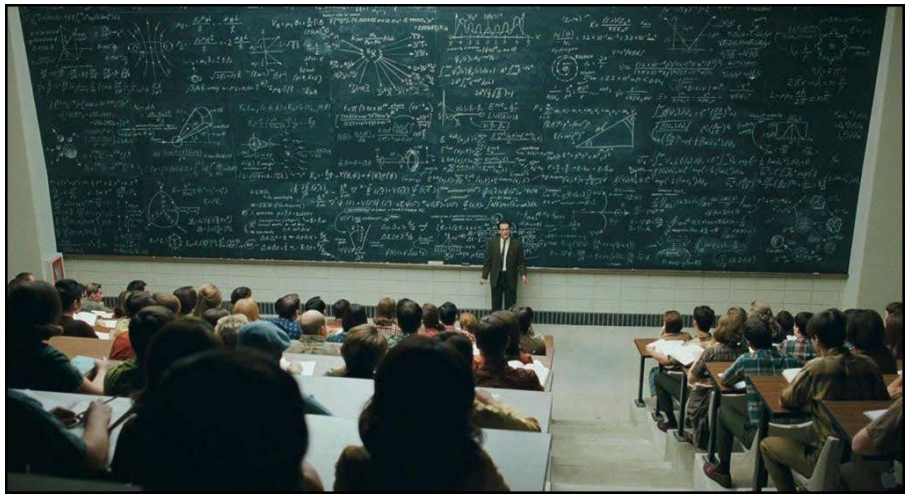
Associate Director, Montana Engineering Education Research Center
Assistant Professor, Mechanical & Industrial Engineering

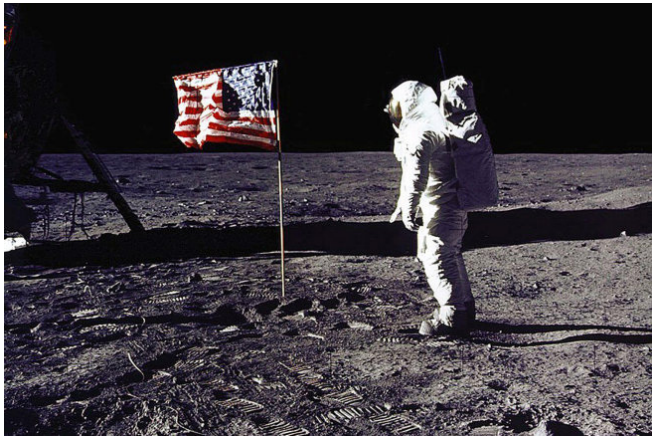
MONTANA STATE UNIVERSITY
College of ENGINEERING
Montana Engineering Education Research Center

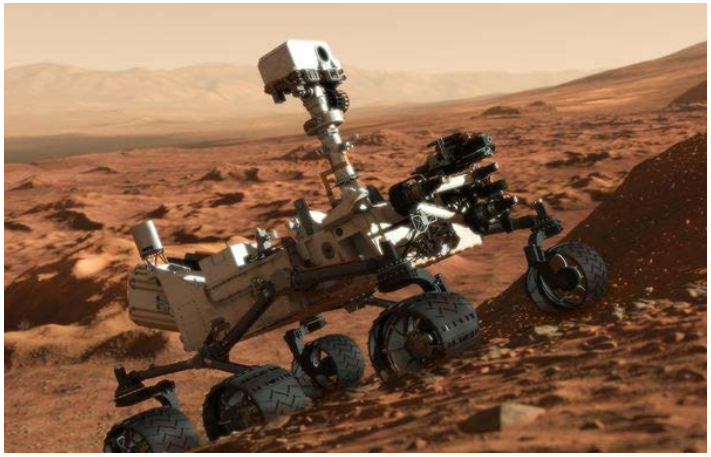
Mission:

Transform engineering education through collaborative, empirical research.



- **Why Transform?**
  - Look at what our current model has gotten us…





Life is good!

Why Transform Engineering Education?

- **Life is Good**
  - It might actually be **TOO** good.



  - **Good engineering is invisible**
  - Most of us don't think about where any of our technology comes from.

- **Life is Good**
  - When was the last time you thought about the lower levels of Maslow's Hierarchy?

Technology is covering these.

- **Life is Good**
  - When was the last time you thought about the lower levels of Maslow's Hierarchy?

Living up here isn't a <u>BAD</u> thing...

Technology is covering these.

- **Life is Good**
  - When was the last time you thought about the lower levels of Maslow's Hierarchy?

Living up here isn't a BAD thing...

But this isn't going away

Technology is covering these.

- **Life is Good**
  - With a shift to living in cities, we have created “localized utopias”.
  - We push the negative side-effects of technology down the road (*or off-shore*)

College-Town USA

the shining city upon a hill…

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College-Town USA

the shining city upon a hill…

Colstrip

AK Pipeline

Bakken

Why Transform Engineering Education?

- **Life is Good** *for how long…*

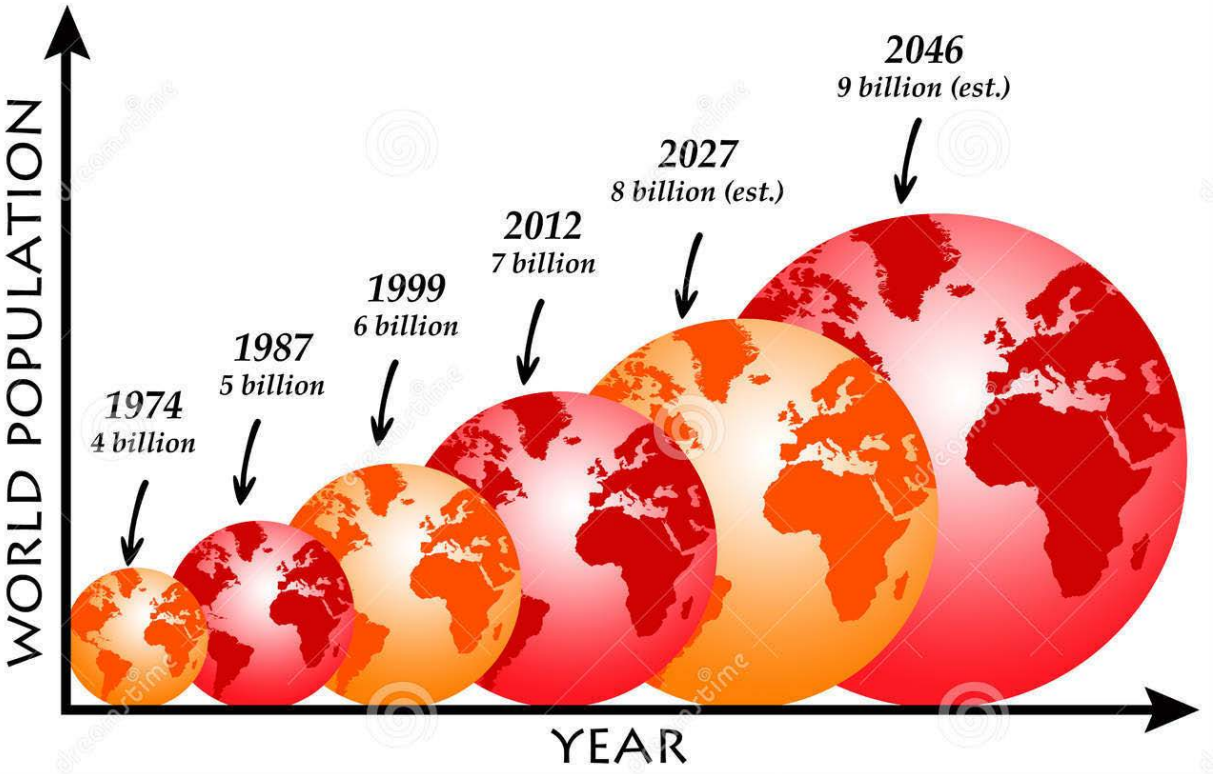
- **Life is Good** *for how long…*

Problems building on a grander scale than ever seen before:

- *Global Warning*
- *Refugee crises*
- *Overpopulation*
- *Drought*
- *Extreme Weather*

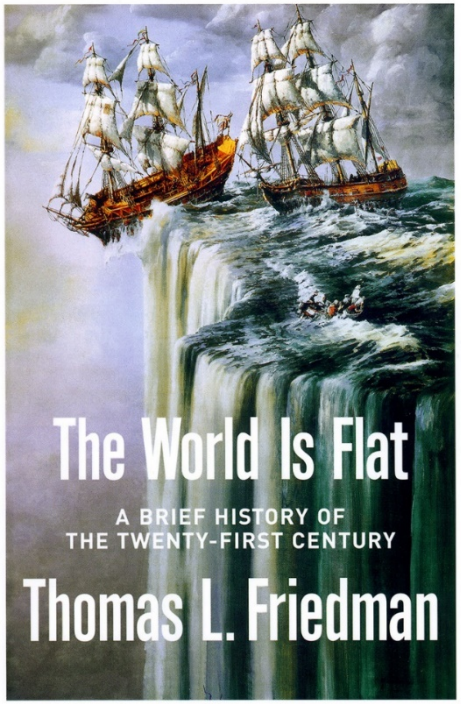
Why Transform Engineering Education?

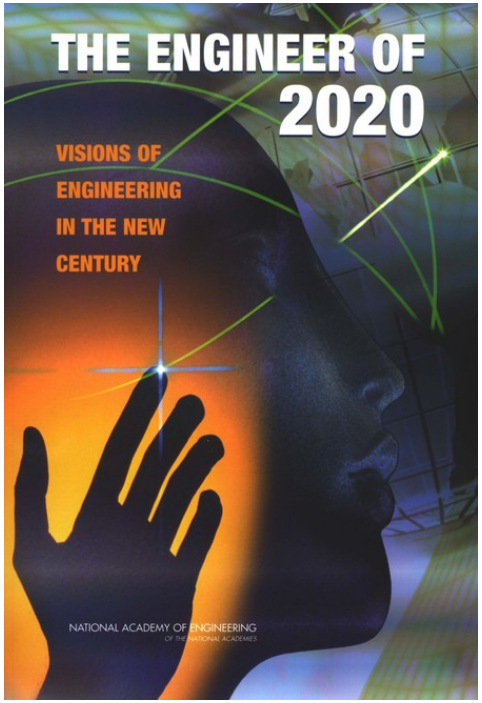
- **Life is Good** *for how long…*
  - *Can our planet sustain 9B people by 2045?*
  - *70% will live in urban areas*

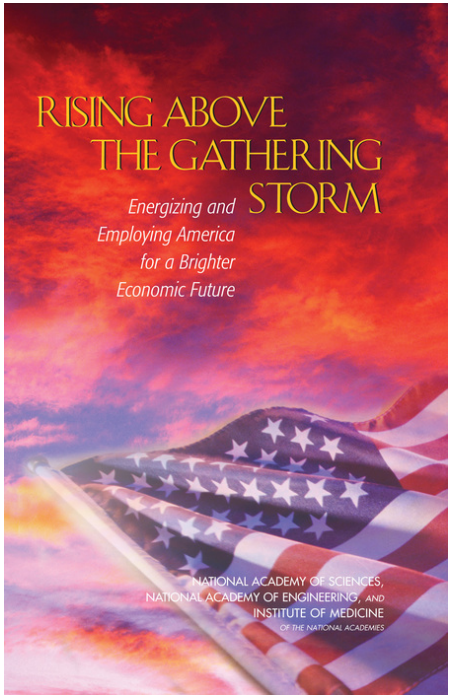


- **A call from the National Academy of Engineering**

  - Problems are getting more complex.
  - Engineers will play an even more important role in the future.







What does Transformation look like?

- **Four overarching themes:**

  1. **Preparing engineering students to meet the grand challenges of the 21st century**

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2. **Broadening Participation in the Engineering Workforce**

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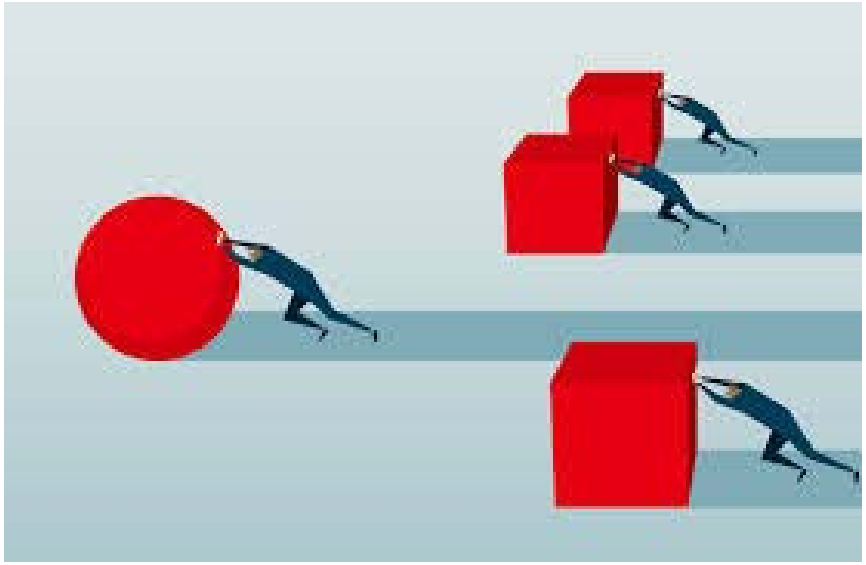
1. Preparing engineering students to meet the grand challenges of the 21st century
2. Broadening Participation in the Engineering Workforce
3. **Improve Efficiency of Learning**



3. Improve Efficiency of Learning

- We are on the precipice of a financial collapse.

- 1.3T Debt.
- #2 consumer debt behind mortgage.
- 44M overall borrowers.
- 22M with federal loans.
- $37k average debt.

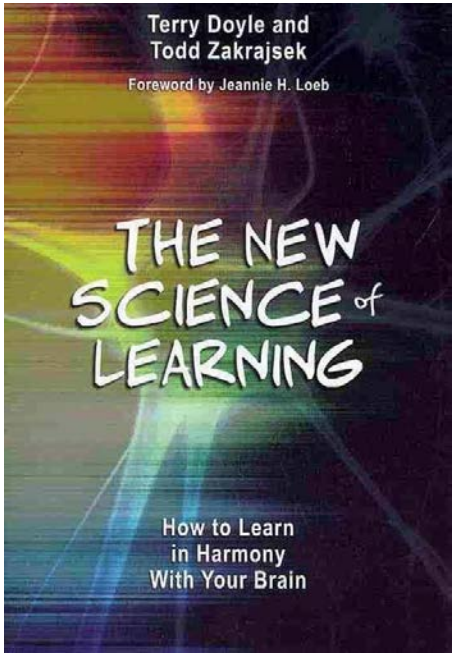
3. Improve Efficiency of Learning

- More than money & time…
- Efficiency includes:

- high impact pedagogical approaches

- personalized learning using technology

- lifelong learning in both formal & informal environments



What does Transformation look like?

- **Four overarching themes:**

1. Preparing engineering students to meet the grand challenges of the 21st century
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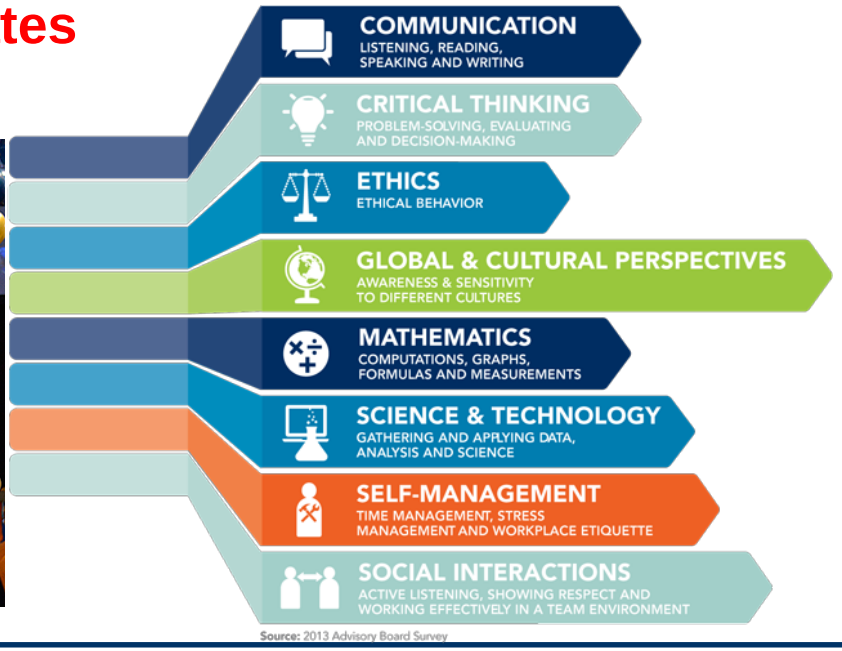
3. Improve Efficiency of Learning
4. **Aligning the Skills of our Graduates to the Needs of the Workforce**



4. Aligning the Skills of our Graduates to the Needs of the Workforce

- What is the engineering **workforce** calling for?

  - ❑ Technical Knowledge
  - ❑ Effective Communication Skills
  - ❑ Interpersonal Skills
  - ❑ Ability to work on an interdisciplinary team
  - ❑ Organizational Skills
  - ❑ Desire to Learn
  - ❑ Leadership and Management Skills

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AKA "Professional Skills"

Often dismissed by engineering faculty as being "soft skills"

- **Solution 1 – The "Engineering Education Researcher"**
  - **2006, the National Academy of Engineers calls for a new type of scholar.**
  - **This scholar will work across disciplinary boundaries never broached before.**
  - **This scholar will create systems and processes for engineering education.**

JEE THE RESEARCH JOURNAL FOR ENGINEERING EDUCATION

ASEE

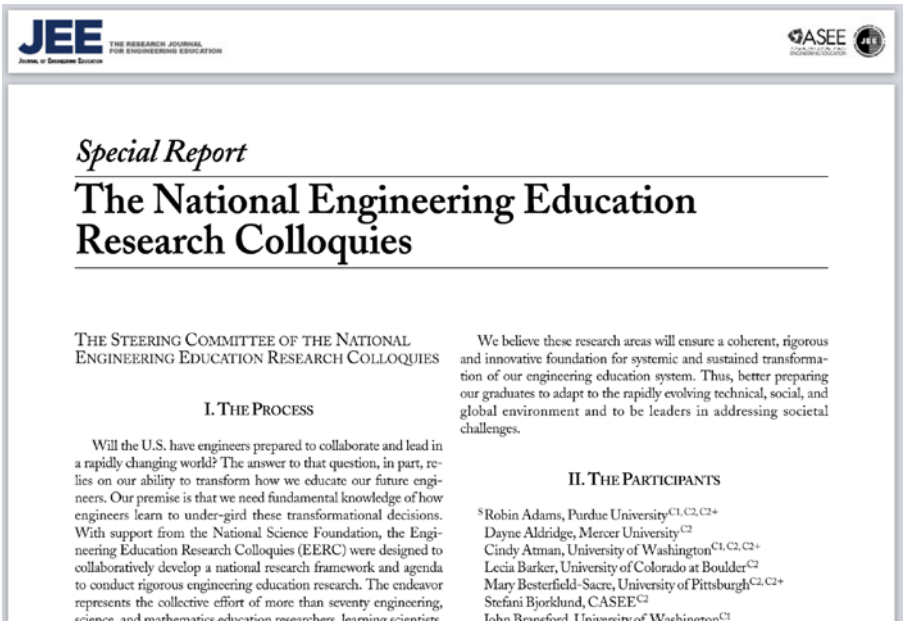
Special Report

The Research Agenda for the New Discipline of Engineering Education

I. Introduction

Rapid changes in the worldwide engineering enterprise are creating a compelling rationale for us to rethink how we should educate future generations of engineers [1–4]. According to *The Engineer of 2020* [5], tomorrow's graduate will need to collaboratively contribute expertise across multiple perspectives in an emerging global economy that is fueled by rapid innovation and marked by an astonishing pace of technological breakthroughs. Deteriorating urban infrastructures, environmental degradation, and the need to provide housing, food, water, and health care for eight billion people will challenge the analytical skills and creativity of engineers. From a U.S. perspective, a continuing decline in interest by American youths in engineering, a shrinking capacity for technological innovation, and an engineering research infrastructure in distress are early warning signs that the nation's prosperity and security are at stake if we fail to take action. Our leadership and capacity for innostage and position us to begin addressing national and global grand challenges.

The Engineering Education Research Colloquies (EERC) were designed with this transformational change in mind [9]. Representing a collaborative effort of more than 70 engineering, science, and mathematics educators and researchers, learning scientists, and practitioners, EERC participants worked to address the challenges and future needs of engineering education. This report presents five research areas that will collectively serve as the foundation for the new discipline of Engineering Education. We envision a synergistic research agenda that will profoundly enhance the U.S. capacity to educate future engineers by shaping our understanding of: what content (knowledge and skills in context) future engineers must possess; how said content is being learned; and how learning of the content should be assessed. This research in turn will inform how the content should be taught as well as how future leaning environments should be designed. Finally, understanding these fun-



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Special Report

The National Engineering Education Research Colloquies

The Steering Committee of the National Engineering Education Research Colloquies

I. The Process

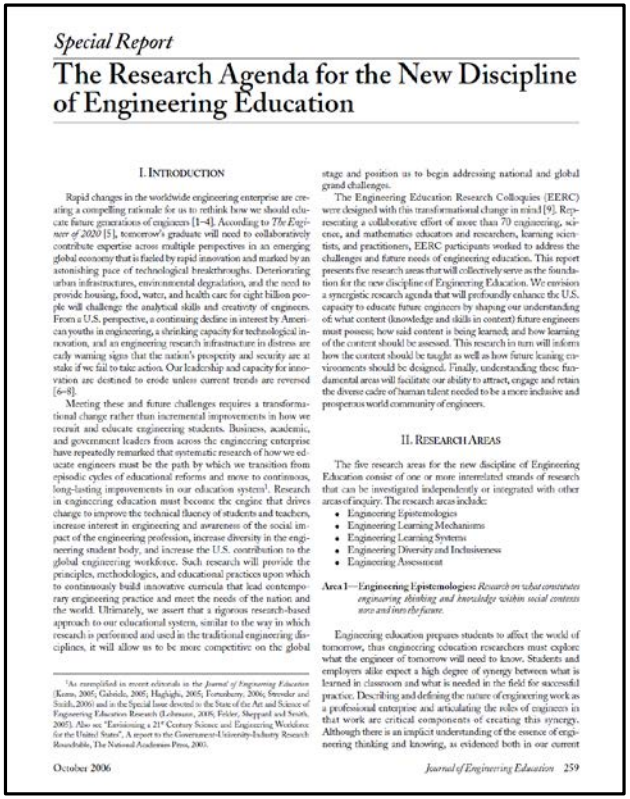
Will the U.S. have engineers prepared to collaborate and lead in a rapidly changing world? The answer to that question, in part, relies on our ability to transform how we educate our future engineers. Our premise is that we need fundamental knowledge of how engineers learn to under-gird these transformational decisions. With support from the National Science Foundation, the Engineering Education Research Colloquies (EERC) were designed to collaboratively develop a national research framework and agenda to conduct rigorous engineering education research. The endeavor represents the collective effort of more than seventy engineering,

We believe these research areas will ensure a coherent, rigorous and innovative foundation for systemic and sustained transformation of our engineering education system. Thus, better preparing our graduates to adapt to the rapidly evolving technical, social, and global environment and to be leaders in addressing societal challenges.

II. The Participants

§Robin Adams, Purdue University[C1, C2, C2+]
Dayne Aldridge, Mercer University[C2]
Cindy Atman, University of Washington[C1, C2, C2+]
Lecia Barker, University of Colorado at Boulder[C2]
Mary Besterfield-Sacre, University of Pittsburgh[C2, C2+]
Stefani Bjorklund, CASEE[C2]

- **Solution 1 – The "Engineering Education Researcher"**
  - **Research across five areas should create knowledge in:**
    - Engineering Epistemologies
    - Engineering Learning Mechanisms
    - Engineering Learning Systems
    - Engineering Diversity and Inclusion
    - Engineering Assessment
  - **This research should:**
    - Continuously shape engineering curriculums
    - Provide faculty pedagogical tools



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Meeting these and future challenges requires a transformational change rather than incremental improvements in how we recruit and educate engineering students. Business, academic, and government leaders from across the engineering enterprise have repeatedly remarked that systematic research of how we educate engineers must be the path by which we transition from episodic cycles of educational reforms and move to continuous, long-lasting improvements in our education system[1]. Research in engineering education must become the engine that drives change to improve the technical fluency of students and teachers, increase interest in engineering and awareness of the social impact of the engineering profession, increase diversity in the engineering student body, and increase the U.S. contribution to the global engineering workforce. Such research will provide the principles, methodologies, and educational practices upon which to continuously build innovative curricula that lead contemporary engineering practice and meet the needs of the nation and the world. Ultimately, we assert that a rigorous research-based approach to our educational system, similar to the way in which research is performed and used in the traditional engineering disciplines, it will allow us to be more competitive on the global stage and position us to begin addressing national and global grand challenges.

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II. Research Areas

The five research areas for the new discipline of Engineering Education consist of one or more interrelated strands of research that can be investigated independently or integrated with other areas of inquiry. The research areas include:

- Engineering Epistemologies
- Engineering Learning Mechanisms
- Engineering Learning Systems
- Engineering Diversity and Inclusiveness
- Engineering Assessment

Area 1—Engineering Epistemologies: *Research on what constitutes engineering thinking and knowledge within social contexts now and into the future.*

Engineering education prepares students to affect the world of tomorrow, thus engineering education researchers must explore what the engineer of tomorrow will need to know. Students and employers alike expect a high degree of synergy between what is learned in classroom and what is needed in the field for successful practice. Describing and defining the nature of engineering work as a professional enterprise and articulating the roles of engineers in that work are critical components of creating this synergy. Although there is an implicit understanding of the essence of engineering thinking and knowing, as evidenced both in our current

[1]As exemplified in recent editorials in the *Journal of Engineering Education* (Koro, 2005; Gabriele, 2005; Haghighi, 2005; Fortenberry, 2006; Streveler and Smith, 2006) and in the Special Issue devoted to the State of the Art and Science of Engineering Education Research (Lohmann, 2008; Felder, Sheppard and Smith, 2005). Also see "Envisioning a 21st Century Science and Engineering Workforce for the United States", A report to the Government-University-Industry Research Roundtable, The National Academies Press, 2000.

October 2006 *Journal of Engineering Education* 259

- **Solution 1 – The "Engineering Education Researcher"**

Engineering

Knowledge

Grand Challenges	**Broadening Participation**	**Learning Efficiency**	**Workforce Skills**
global context, ethics, sustainability, geo-political issues	social justice, diversity	pedagogy, learning, cost impact	management, leadership

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Fields

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political science, sociology, philosophy	psychology, social psychology	education

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Fields

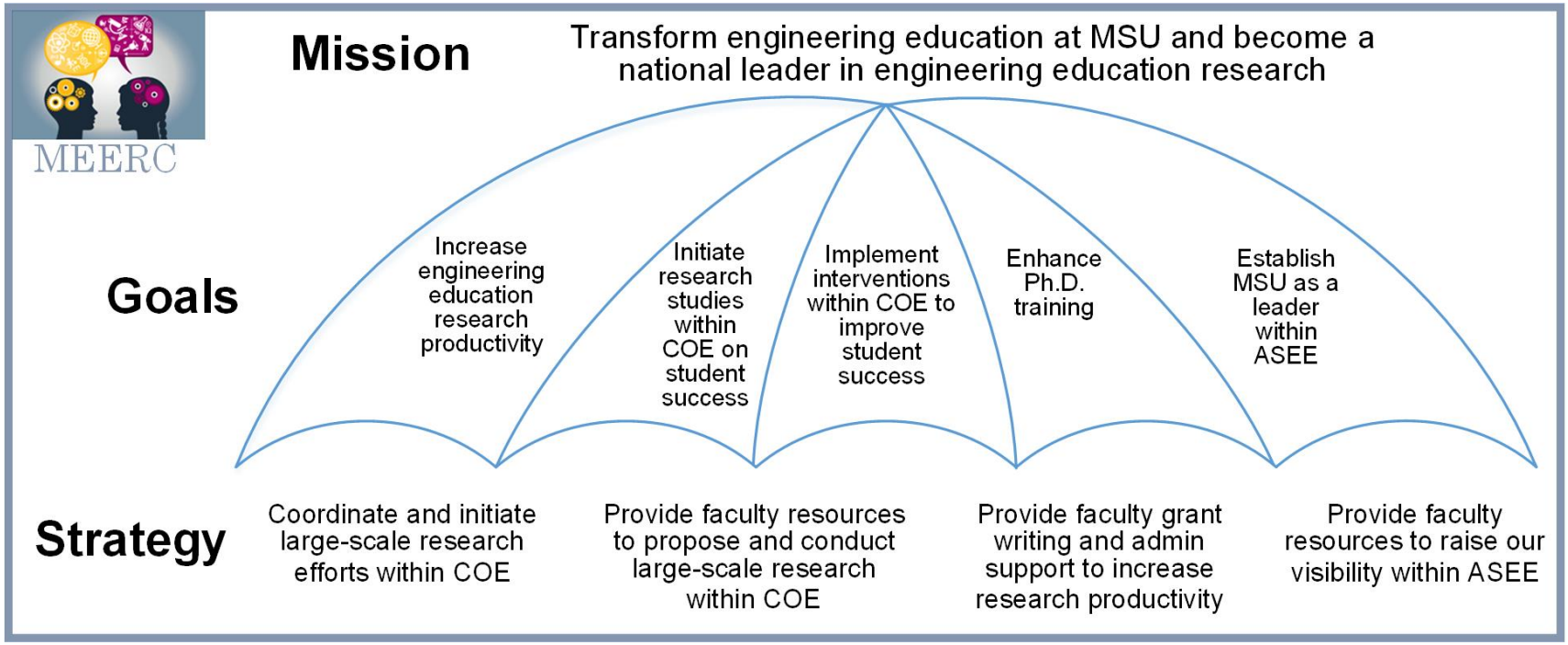
political science, sociology, philosophy	psychology, social psychology	education	business

- **Solution 2 – Dynamic Engineering Curriculums**
  - **Curriculums that can make continual tweaks to research findings.**
  - **Faculty that are engaged in continual change.**

- **Solution 3 – Engineer Leadership**
  - **How does the world change if the "global-thinking engineer":**
    - **Engages in policy discussions?**
    - **Engage in discussions about state funding of higher education?**
    - **Engages in integrating engineering in the K-12 continuum?**
    - **Brings ethical thinking to the highest levels of corporate America?**

- **The MEERC's Mission to contribute to the NAE call.**

1. Preparing engineering students to meet the grand challenges of the 21st century.
2. Broadening Participation in the Engineering Workforce.
3. Improve Efficiency of Learning.
4. Aligning the Skills of our Graduates to the Needs of the Workforce.



MEERC Timeline

- **2006-2014** **-** Organic growth of engineering education research at MSU. Four independent Education Grants (2x IUSE, 2x RIEF).
- **2015** - Engaged faculty decide to organize.
  - Begin year long approval process to form center.
- **2016** - MT Board of Regents approve center.

What We Want To Do

- **Build Engineering Education Research Capacity**

Phase 1

– Building connections between faculty with similar interests from across disciplines (engineering, social psychology, education).

– Start writing proposals. Grow research expenditures in EER.

Phase 2

– Use funded EER to fuel increased publications, increased participation in EER, and interventions to increases success of MSU.

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But as things get going, there are rumblings among engineering faculty about this not being a worthwhile scholarly pursuit.

Polling the COE Faculty

- **In November 2016, a COE survey is sent to COE faculty to gauge opinions about EER as a new initiative in the college.**
  (66 responses out of 101 faculty)

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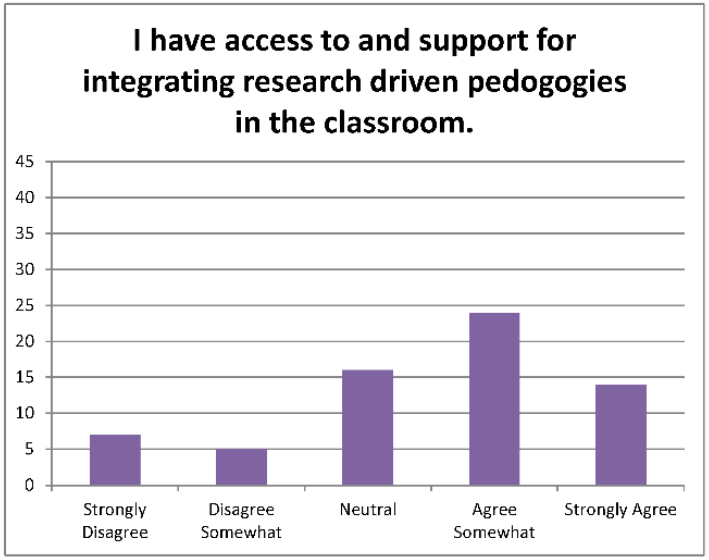
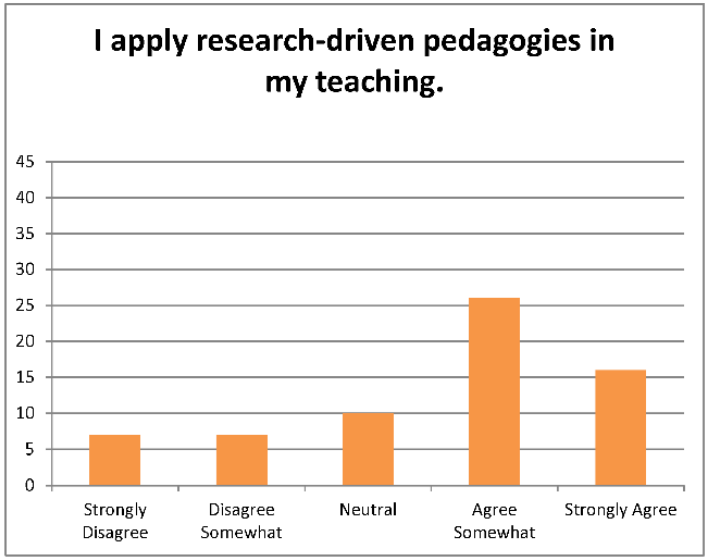
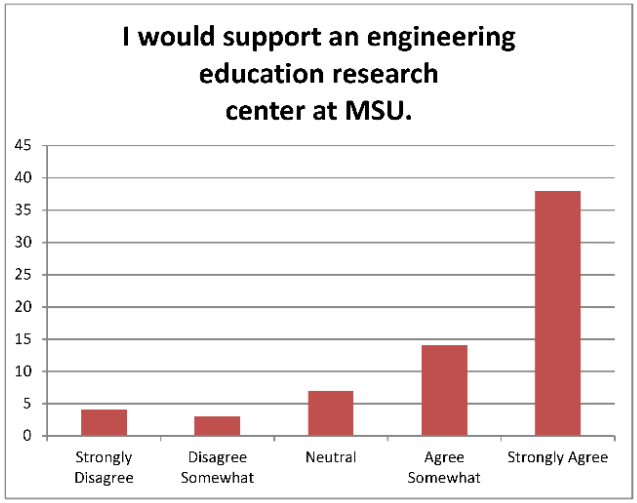
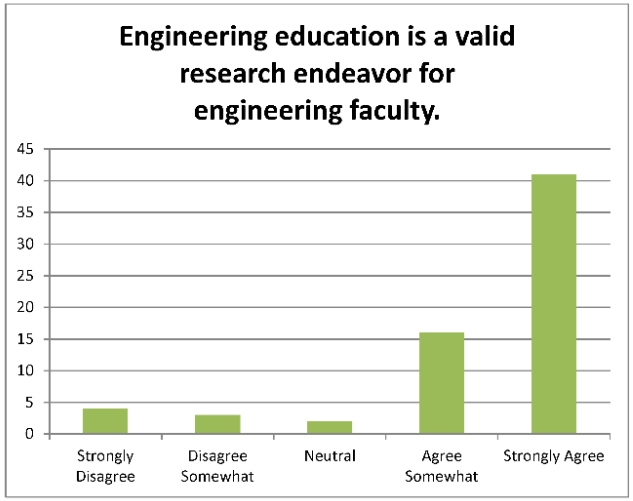
Questions Regarding Using Modern Pedagogies in their Own Classes

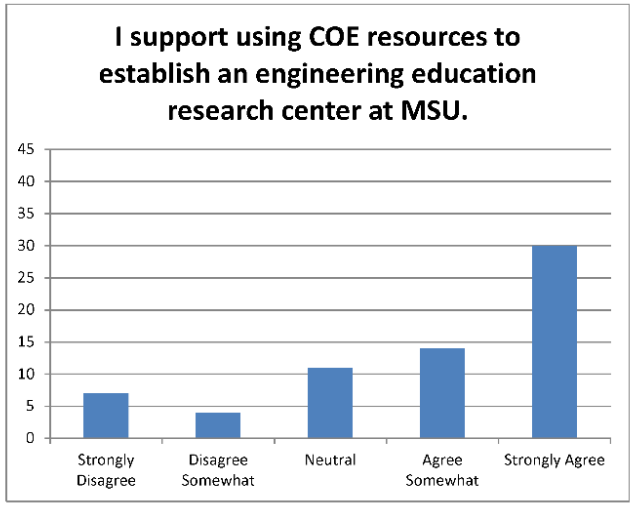




Questions Regarding EER as a Worthy Scholarly Pursuit







Questioning the COE Faculty

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  1) How can this center serve the college?

  2) What obstacles do you see that will prevent us from increasing research productivity in this area?

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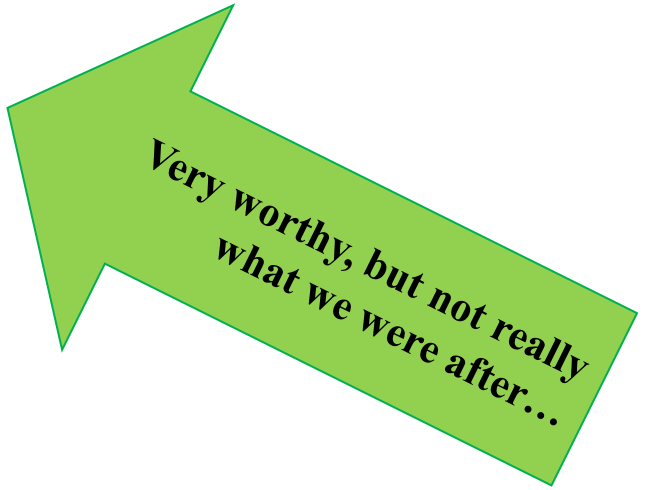
  - Provide training on effective pedagogical methods to the engineering faculty

  - Serve as a central point of contact for all questions related to teaching and learning.



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  - Negative Impact on Promotion & Tenure
  - Lack of Graduate Students

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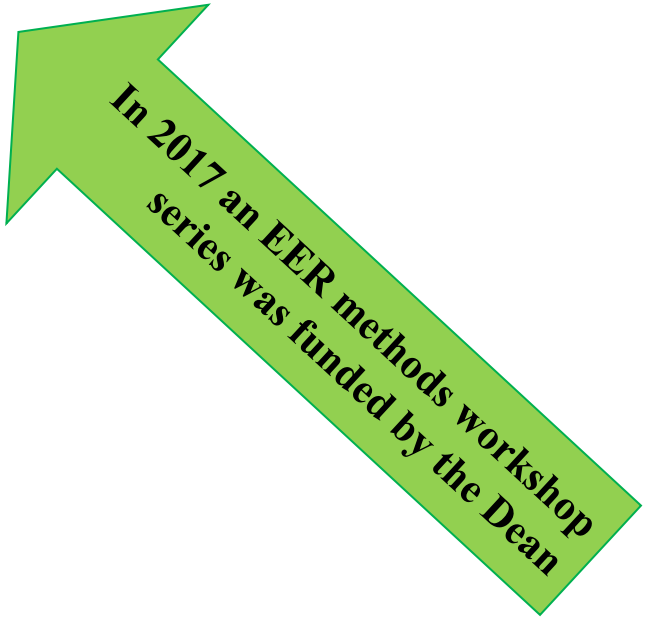

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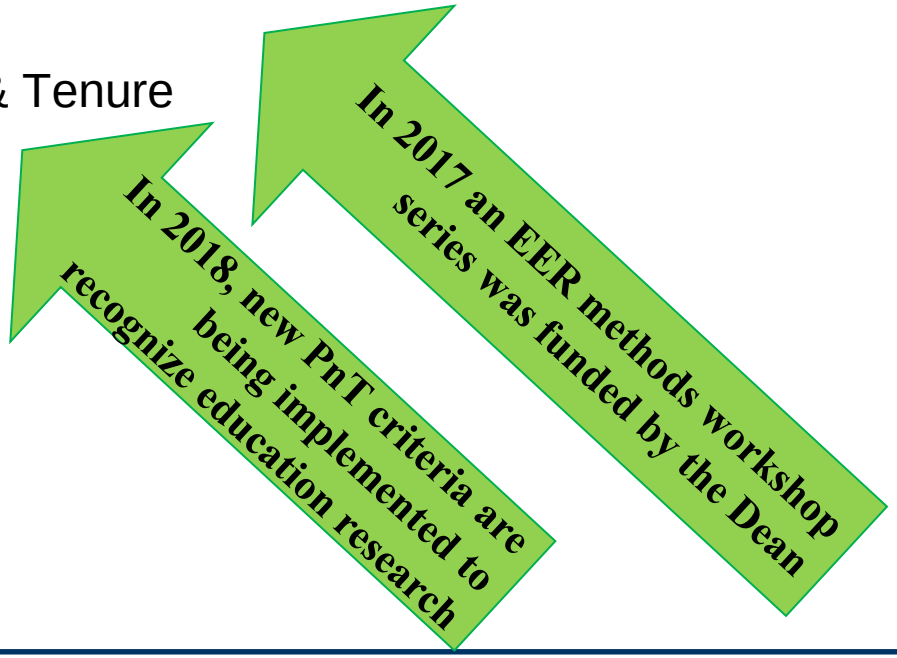

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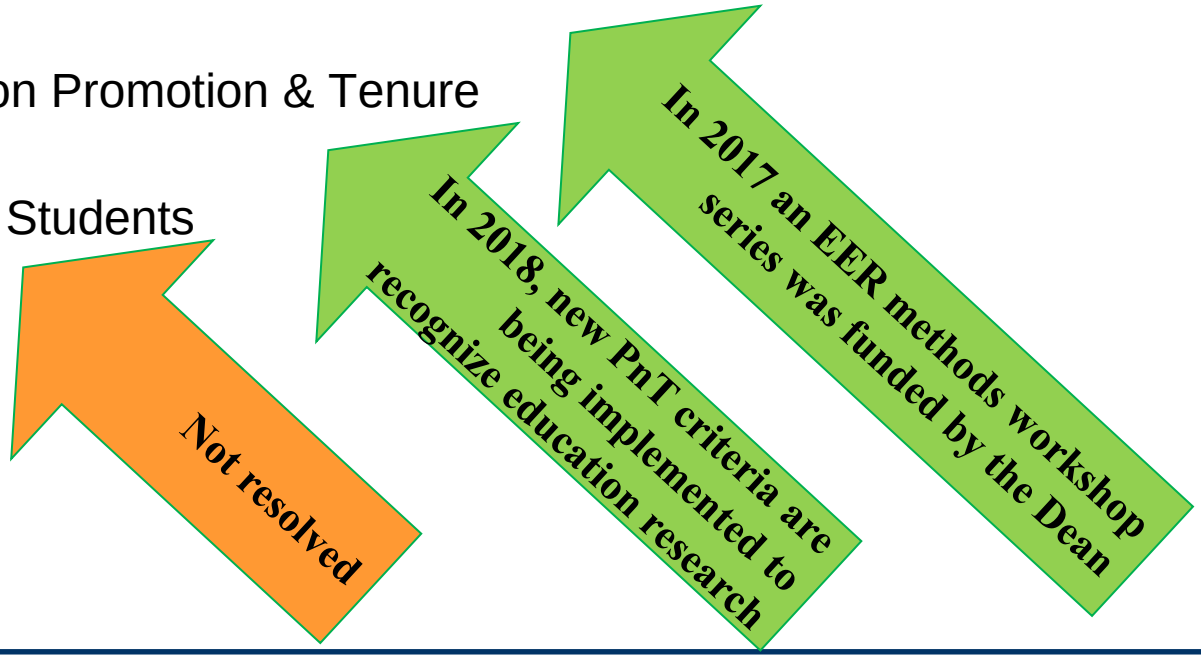


Some Early Successes

- **Increased External EER Funding 400% within 1st year.**
  ($800k to $3.2M)

NSF Division of Education and Centers
Engineering Education Program

MONTANA STATE UNIVERSITY | College of ENGINEERING

PFE:RIEF Program Fuels Expansion of Engineering Education Research at Montana State University

In 2015, two PFE:RIEF grants to MSU set in motion a series of events that has resulted in an expansive community of researchers studying engineering education. Dr. LaMeres and Dr. Gannon each received research initiation grants from the PFE:RIEF program to enhance their ability to conduct education research. As the two began collaborating on workshop ideas, they discovered that there were other faculty at MSU that had similar interests and wanted to join forces. The growing community decided to establish a formal *Center* to serve as the infrastructure for their research. In September of 2016, the "Montana Engineering Education Research Center", or MEERC, was approved by the MT Board of Regents.

PI: Brock LaMeres (ECE)
Award No: 1544147 (PFE:RIEF)
Title: Research Initiation - Engineering a Culture of Engagement

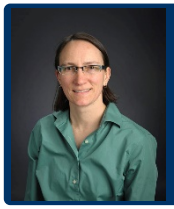
PI: Paul Gannon (ChemE/BioE)
Award No: 1544174 (PFE:RIEF)
Title: Research Initiation - Effectively Integrating Sustainability into Engineering

In the first 10 months of MEERC's operation, four NSF education research proposals have been selected for funding by NSF. MSU now has $3.2M of active NSF funding supporting efforts to create knowledge and test strategies to improve engineering education.

PI: William Schell (ME)
Award No: 1664231 (PFE)
Title: The Formation of Undergraduate Engineers as Engineering Leaders

PI: Brittany Fasy (CS)
Award #: 1657553 (ITEST)
Title: Improving the Pipeline for American Indian Students Entering CS Via Storytelling

PI: Nick Lux (Education)
Award No: 1720801 (DRK12)
Title: Designing a Middle Grades Spatial Skills Curriculum



PI: Shannon Willoughby (Physics)
Award No: 1735124 (DRT)
Title: Fostering Effective Oral Communication Skills for STEM Graduate Students

In July 2017, the directors of the MEERC (LaMeres, Gannon, and Schell) received funding from the MSU College of Engineering for a project titled "Expanding Engineering Education Research Capacity in the COE".

The MEERC now has 20 active affiliate faculty.

MEERC affiliates published 9 papers at the 2017 ASEE Annual Conference.

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In Closing… The Next Steps

- **Continue to write proposals to engage more faculty in EER.**
  (there is a limit)
- **Push for publishing results in peer reviewed journals.**
- **Figure out a strategy for engaging graduate students in EER within the constructs of Montana State University.**

Questions