Leveraging Your Engineering Education Innovation

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National Academy of Engineering

Frontiers of Engineering Education Symposium

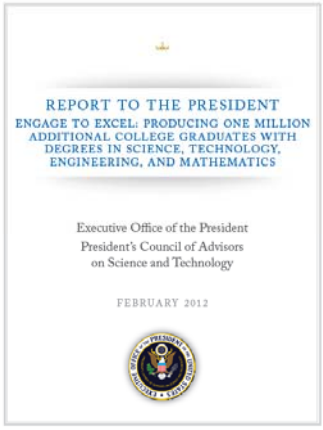
October, 2012

Participant Learning Goals (Objectives)

- Describe key features of recent engineering education innovation and research reports
- Explain rationale for national and international emphasis on engineering education innovation and research
- Apply findings and/or recommendations to your engineering education innovation
- Identify connections between national reports and how to leverage key aspects to advance your innovation.

Reflection and Dialogue

- Individually reflect on findings that would help support/leverage your engineering education innovation. Write for about 1 minute.
  - Recall reports you have reviewed or
  - Speculate on areas of emphasis that would help support your innovation
- Discuss with your neighbor for about 2 minutes
  - Describe your lists and talk about similarities and differences
- Whole group discussion

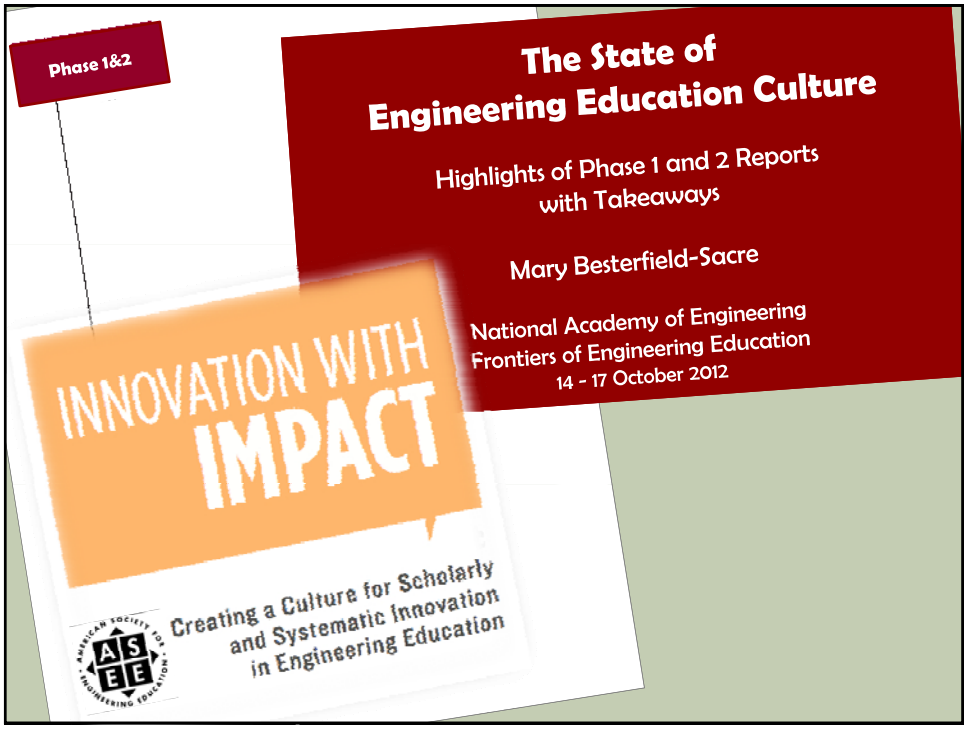


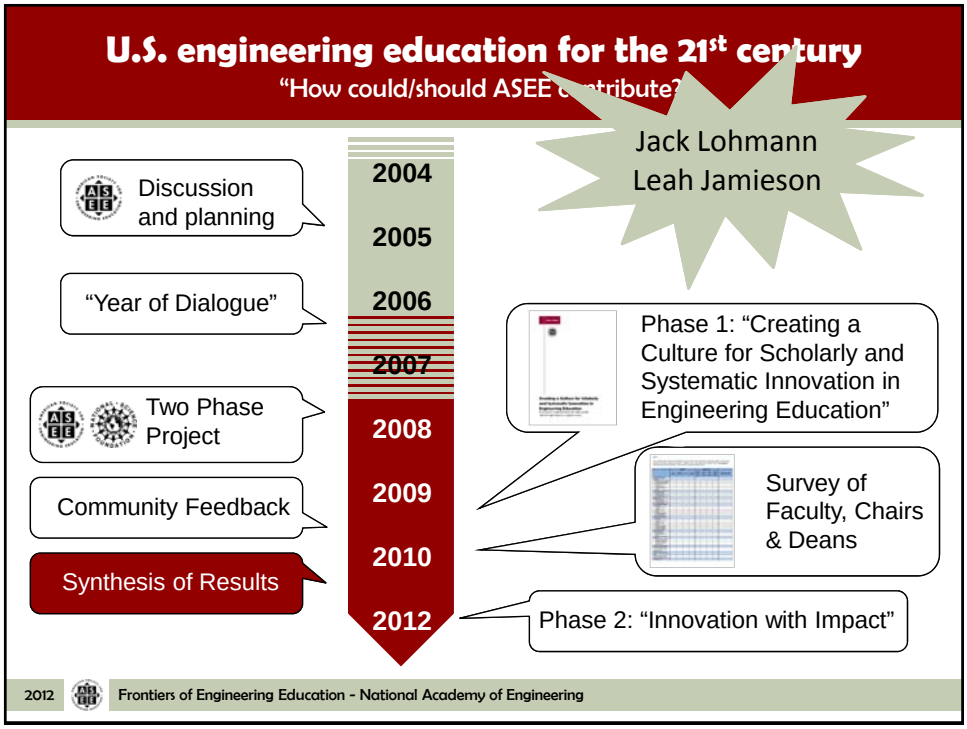
Summary of President's Council of Advisors on Science and Technology (PCAST) Report Dated February 2012

James M. Tien, PhD, DEng (*h.c.*), NAE
Distinguished Professor and Dean

Report's Foci

- **Mission:** Producing 1M Additional STEM Graduates
- **Vision:** Engaging Students, Faculty and Government
- **Approach:**
  - Increasing Retention Rate From 40% to 50% (Would Yield Additional 0.75M Graduates!)
  - Requiring Faculty To Better Inspire and Motivate Students
  - Adopting Empirically Validated Teaching Practices
  - Replacing Standard Lab Courses With Discovery-Based Research Courses
  - Launching Postsecondary Mathematics Education To Address Math Gap
  - Encouraging Partnership Among Stakeholders
  - Creating A Presidential Council on STEM Education


Phase 1&2
The State of Engineering Education Culture
Highlights of Phase 1 and 2 Reports with Takeaways
Mary Besterfield-Sacre
National Academy of Engineering
Frontiers of Engineering Education
14 - 17 October 2012
INNOVATION WITH IMPACT
Creating a Culture for Scholarly and Systematic Innovation in Engineering Education


U.S. engineering education for the 21st century
"How could/should ASEE contribute?
Jack Lohmann
Leah Jamieson
Discussion and planning
"Year of Dialogue"
Two Phase Project
Community Feedback
Synthesis of Results
2004
2005
2006
2007
2008
2009
2010
2012
Phase 1: "Creating a Culture for Scholarly and Systematic Innovation in Engineering Education"
Survey of Faculty, Chairs & Deans
Phase 2: "Innovation with Impact"
2012
Frontiers of Engineering Education - National Academy of Engineering

a universal and fundamental question…

…and the report's major recommendation

Q: "How can we create an environment in which many exciting, engaging, and empowering engineering educational innovations can flourish and *make a significant difference* in educating future engineers?"

A: "Create and sustain a vibrant engineering academic culture for ***scholarly and systematic educational innovation*** — just as we have for technological innovation — to ensure that the U.S. engineering profession has the right people with the right talent for a global society."

"who" should drive change?

engineering education depends on many stakeholders, but…

…engineering faculty and administrators are key

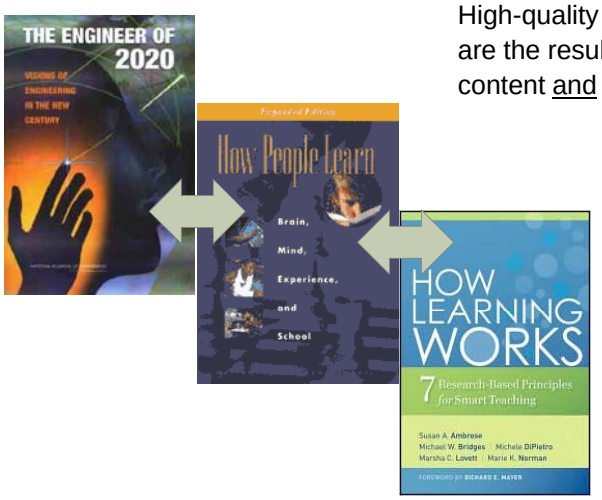
They determine the content of the program, decide how it is delivered, and shape the environment in which it is offered

We need to –

- strengthen career-long professional development
- create supportive environments
- form broader collaborations

"what" change is needed?

integrate what we know about engineering with what we know about learning



High-quality learning environments are the result of attention to both content and **how people learn**

There is ample evidence that our engineering programs need to be more –

- engaging
- relevant
- welcoming

"how" to drive change

connecting communities

Engineering education innovation depends on a **vibrant community of scholars and practitioners working in collaboration** to advance the frontiers of knowledge and practice…and it also depends on support –

- Adequate fiscal resources
- Appropriate facilities
- Reputable journals
- Highly-regarded conferences
- Prestigious recognitions

Phase 2 – feedback and a baseline study

heart of the feedback — two samples of engineering programs

Research Team

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University of Pittsburgh

Maura J. Borrego
Virginia Tech

Monica F. Cox
Purdue University

Barbara M. Olds
Colorado School of Mines
NSF

156 Engineering Schools invited

Random Sample
100 colleges and 200 designated departments selected randomly

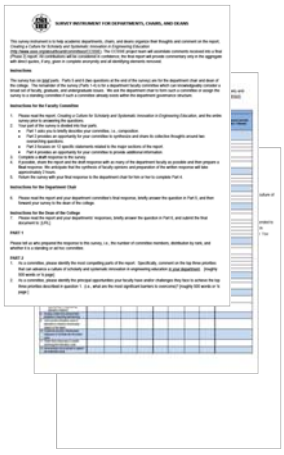
Focused Sample
73 "Top 20" colleges and ~140 undesignated departments by selected attributes (e.g., size, degrees, diversity)

Carnegie Classification
26 Bachelors
40 Masters
90 PhD

46% Response Rate

a three-part survey

faculty, chairs, deans



Faculty Committee

Q1: Most compelling parts of the report, specifically, top three priorities?

Q2: Principal opportunities/challenges to achieve priorities?

Quantitative: 12 "check the box" statements

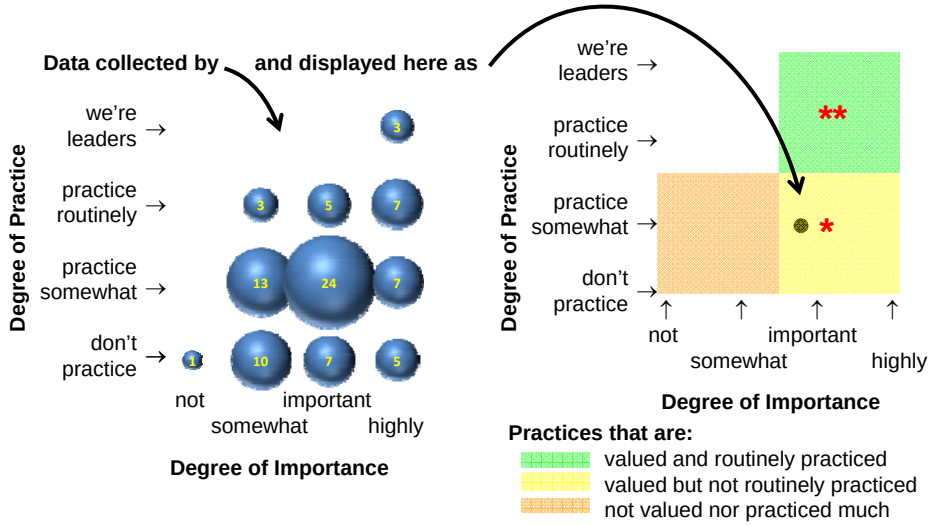
Chairs/Heads & Deans

Q: Principal opportunities/challenges to help create a culture for scholarly and systematic educational innovation in…

… your department? (chair)

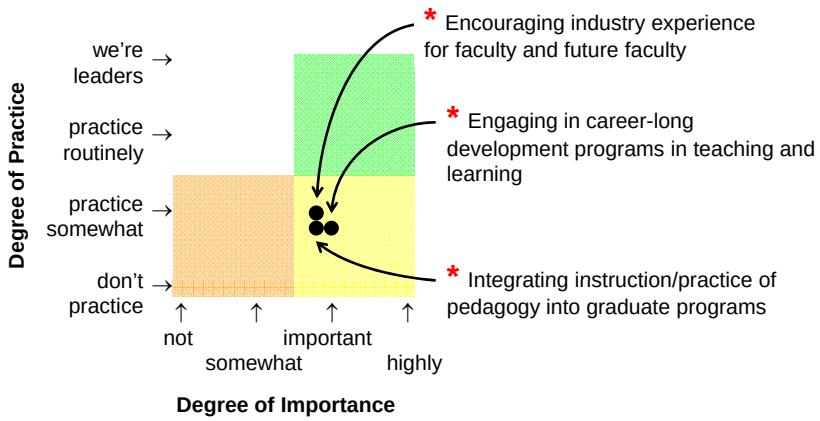
… your college? (dean)

classifying faculty committee results



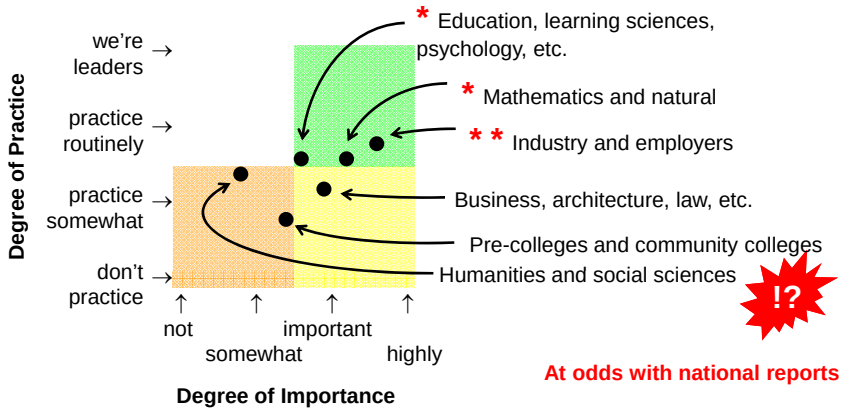
preparing new and future faculty by . . .

who



form broader collaborations with . . .

who

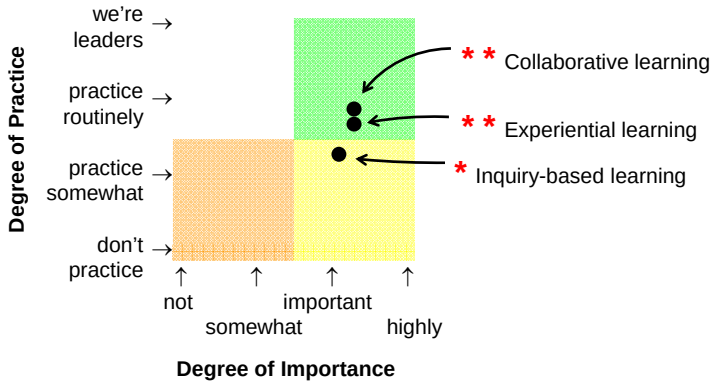


At odds with national reports

broaden pedagogical approaches to include . . .

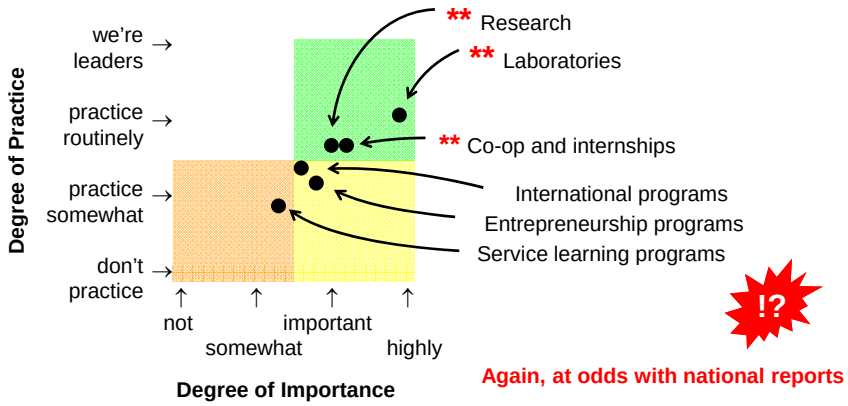
(undergraduate shown, have graduate data, too)

what



engage in educational environments such as . . .

what

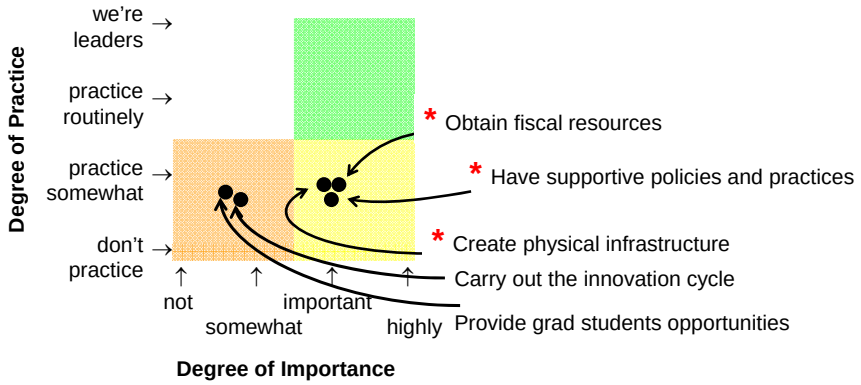


!?

Again, at odds with national reports

supporting communities in innovation

how



...top 5 challenges and opportunities...

Challenges

Faculty	Count	Chairs	Count	Deans	Count
Resources	46	**Resources**	36	**Resources**	19
Rewards	37	**Rewards**	29	**Workload**	17
Workload	36	**Workload**	27	**Rewards**	16
Awareness of Innovations	18	Tech. Research Emphasis	13	Innovation Not Valued	12
Assessment of Innovations	18	Changing the Curriculum	12	Resistance to Change	10
		Awareness of Innovations	12		

Opportunities

Faculty	Count	Chairs	Count	Deans	Count
Faculty Development	16	Faculty Commitment	24	**Rewards**	21
Rewards	15	**Faculty Development**	18	Changing the Curriculum	18
Industry & Entrepreneurship	12	Awareness of Innovations	15	Collaborating with Others	15
STEM Centers	10	Innovative Pedagogy	15	**Faculty Development**	14
Resources	7	**Rewards**	12	Instructional Innovations	14
Changing the Curriculum	7				

a path forward...7 recommendations

who

1. Grow professional development in teaching and learning
   - Career-long PD programs in teaching, learning, and education innovation for faculty and administrators
   - Begin to prepare future faculty
2. Expand collaborations
   - Disciplinary programs relevant to engineers
   - Support the pre-professional, professional, and continuing education of engineers

a path forward...7 recommendations

what

3. Expand efforts to make engineering programs more: engaging, relevant, & welcoming
   - Pedagogy embraced, but changing landscape
   - New learning environments to explore

a path forward...7 recommendations

how

4. Resources
   - Increase, leverage, and diversify for engineering teaching, learning, and innovation
5. Raise awareness
   - Proven practices
   - Scholarship in engineering education

Create a Better Culture!

n forward…7 recommendations

Measure progress in implementing policies, practices, and infrastructure in support of scholarly and systematic innovation in engineering education:

6. Push our individual institutions
   - Vision, shared values, clear goals, careful planning, and commitment to follow through
   - It is up to us to make it happen
7. National capacity for innovation
   - "A seat at the table" as a peer with engineering research

Thank you!

www.asee.org > Member Resources> Reports

Reflect

- Which of the 7 recommendations do you feel is most salient to your innovation. Why?
- What role do you see engineering education research play in your innovation?

Who

1. Grow professional development in teaching and learning.
2. Expand collaborations.

What

3. Expand efforts to make engineering more engaging, relevant, and welcoming.

How

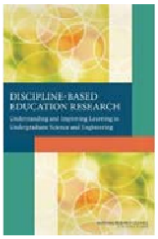
4. Increase, leverage, and diversify resources for engineering teaching, learning, and innovation.
5. Raise awareness of proven practices and of scholarship in engineering education.

Creating a Better Culture

To measure progress in implementing policies, practices, and infrastructure in support of scholarly and systematic innovation in engineering education:

6. Conduct periodic self-assessments in our individual institutions.
7. Conduct periodic community-wide self-assessments.

Discipline-Based Education Research (DBER)

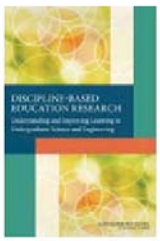


National Research Council 2012

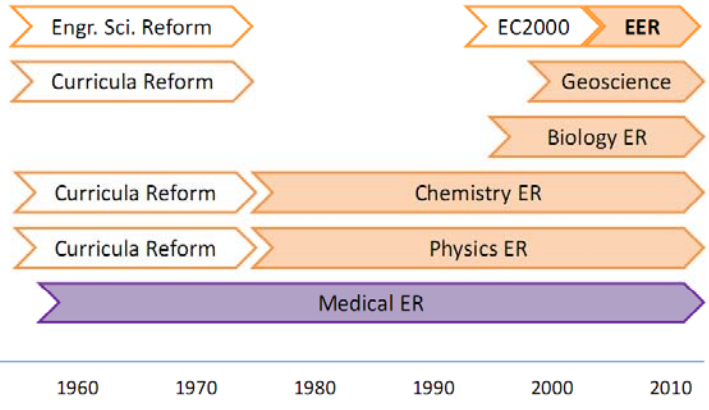
- Discipline-based education research (DBER) is a **small but growing field of inquiry**.
- **Conducting DBER** and **using DBER** findings are **distinct but interdependent** pursuits.
- DBER is **inherently interdisciplinary.**
- Individual fields of DBER have made **notable inroads** in terms of establishing their fields **but still face challenges in doing so**.
- **Blending** a scientific/engineering discipline with education research poses **unique professional challenges for DBER scholars.**
- There are **many pathways to becoming a discipline-based education researcher**.

PURDUE ENGINEERING EDUCATION

Discipline-Based Education Research Timeline



National Research Council 2012



PURDUE ENGINEERING EDUCATION

DBER is **located** in the relevant disciplinary school, e.g. medicine, physics.

SCIENCE EDUCATION AT THE NATIONAL RESEARCH COUNCIL
www.nationalacademies.org/bose

Discipline-Based Education Research (DBER)

Understanding and Improving Learning in Undergraduate Science and Engineering

http://www.nap.edu/catalog.php?record_id=13362

Undergraduate Science and Engineering Education: Goals

- Provide all students with foundational knowledge and skills
- Motivate some students to complete degrees in science or engineering
- Support students who wish to pursue careers in science or engineering

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Undergraduate Science and Engineering Education: Challenges and Opportunities

- Retaining students in courses and majors
- Increasing diversity
- Improving the quality of instruction

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What is Discipline-Based Education Research?

- Emerging from various parent disciplines
- Investigates teaching and learning in a given discipline
- Informed by and complementary to general research on human learning and cognition

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Study Charge

- Synthesize empirical research on undergraduate teaching and learning in physics, chemistry, engineering, biology, the geosciences, and astronomy.
- Examine the extent to which this research currently influences undergraduate science instruction.
- Describe the intellectual and material resources that are required to further develop DBER.

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Committee on the Status, Contributions, and Future Directions of Discipline-Based Education Research

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- **ROBERT BEICHNER**, North Carolina State University
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- **MELANIE COOPER**, Clemson University
- **SEAN DECATUR**, Oberlin College
- **JAMES FAIRWEATHER**, Michigan State University
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- **KIM KASTENS**, Columbia University
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- **KARL A. SMITH**, University of Minnesota and Purdue University
- **WILLIAM B. WOOD**, University of Colorado

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Structure of the Report

- Section I. Status of Discipline-Based Education Research
- Section II. Contributions of Discipline-Based Education Research
- Section III. Future Directions for Discipline-Based Education Research

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Section I. Status of Discipline-Based Education Research

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Status of DBER: Goals

- Understand how people learn the concepts, practices, and ways of thinking of science and engineering.
- Understand the nature and development of expertise in a discipline.
- Help to identify and measure appropriate learning objectives and instructional approaches that advance students toward those objectives.
- Contribute to the knowledge base in a way that can guide the translation of DBER findings to classroom practice.
- Identify approaches to make science and engineering education broad and inclusive.

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Status of DBER: Types of Knowledge Required To Conduct DBER

- Deep disciplinary knowledge
- The nature of human thinking and learning as they relate to a discipline
- Students' motivation to understand and apply findings of a discipline
- Research methods for investigating human thinking, motivation, and learning

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Status of DBER: Conclusions

- DBER is a collection of related research fields rather than a single, unified field. (Conclusion 1)
- High-quality DBER combines expert knowledge of:
  - a science or engineering discipline,
  - learning and teaching in that discipline, and
  - the science of learning and teaching more generally.

  (Conclusion 4)

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Section II. Contributions of Discipline-Based Education Research

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Contributions of DBER: Conceptual Understanding and Conceptual Change

- In all disciplines, undergraduate students have incorrect ideas and beliefs about fundamental concepts. (Conclusion 6)
- Students have particular difficulties with concepts that involve very large or very small temporal or spatial scales. (Conclusion 6)
- Several types of instructional strategies have been shown to promote conceptual change.

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Contributions of DBER: Problem Solving and the Use of Representations

- As novices in a domain, students are challenged by important aspects of the domain that can seem easy or obvious to experts. (Conclusion 7)
- Students can be taught more expert-like problem-solving skills and strategies to improve their understanding of representations.

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Contributions of DBER: Research on Effective Instruction

- Effective instruction includes a range of well-implemented, research-based approaches. (Conclusion 8)
- Involving students actively in the learning process can enhance learning more effectively than lecturing.

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Section III. Future Directions for Discipline-Based Education Research

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Future Directions for DBER: Translating DBER into Practice

- Available evidence suggests that DBER and related research have not yet prompted widespread changes in teaching practice among science and engineering faculty. (Conclusion 12)
- Efforts to translate DBER and related research into practice are more likely to succeed if they:
  - are consistent with research on motivating adult learners,
  - include a deliberate focus on changing faculty conceptions about teaching and learning,
  - recognize the cultural and organizational norms of the department and institution, and
  - work to address those norms that pose barriers to change in teaching practice. (Conclusion 13)

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Future Directions for DBER: Recommendations for Translating DBER Into Practice

- **RECOMMENDATION:** With support from institutions, disciplinary departments, and professional societies, faculty should adopt evidence-based teaching practices.
- **RECOMMENDATION**: Institutions, disciplinary departments, and professional societies should work together to prepare current and future faculty to apply the findings of DBER and related research, and then include teaching effectiveness in evaluation processes and reward systems throughout faculty members' careers. (Paraphrased)

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Future Directions for DBER: Advancing DBER through Collaborations

- Collaborations among the fields of DBER, and among DBER scholars and scholars from related disciplines, although relatively limited, have enhanced the quality of DBER. (Conclusion 15)

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Future Directions for DBER: Research Infrastructure

- Advancing DBER requires a robust infrastructure for research. (Conclusion 16)
- **RECOMMENDATION**: Science and engineering departments, professional societies, journal editors, funding agencies, and institutional leaders should:
  - clarify expectations for DBER faculty positions,
  - emphasize high-quality DBER work,
  - provide mentoring for new DBER scholars, and
  - support venues for DBER scholars to share their research findings

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Future Directions for DBER: Some Key Elements of a Research Agenda

- Studies of similarities and differences among different groups of students
- Longitudinal studies
- Additional basic research in DBER
- Interdisciplinary studies of cross-cutting concepts and cognitive processes
- Additional research on the translational role of DBER

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- National Science Foundation, Division of Undergraduate Education (Grant No. 0934453)
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  - Committee
  - Fifteen reviewers
  - Report Review Monitor (Susan Hanson, Clark University) and Coordinator (Adam Gamoran, University of Wisconsin-Madison)
- Commissioned paper authors
- NRC staff (Natalie Nielsen, Heidi Schweingruber, Margaret Hilton)

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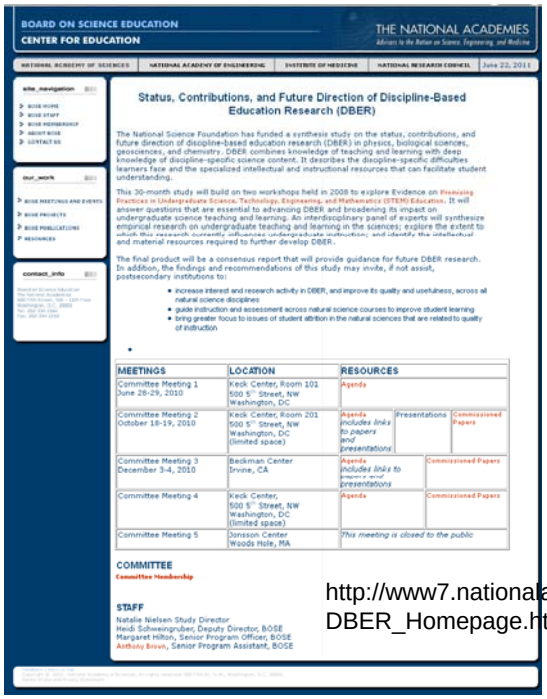

http://www7.nationalacademies.org/bose/DBER_Homepage.html

Reflection and Dialogue

- Add to your reflection, your additional insights and connections gained from the DBER. Write for about 1 minute.
  - List supporting points
  - Articulate connections that would help leverage and/or support your innovation
- Discuss with your neighbor for about 2 minutes
  - Describe your lists and talk about similarities and differences
- Whole group discussion

Recent Reports/Initiatives

- National Research Council Discipline-Based Education Research (DBER)
  - http://www.nap.edu/catalog.php?record_id=13362
- ASEE Innovation with Impact report
  - http://www.asee.org/about-us/the-organization/advisory-committees/Innovation-with-Impact
- Froyd, J.E., Wankat, P.C. & Smith, K.A. (2012). Five major shifts in 100 years of engineering education. *Proceedings of the IEEE*
  - http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=06185632

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