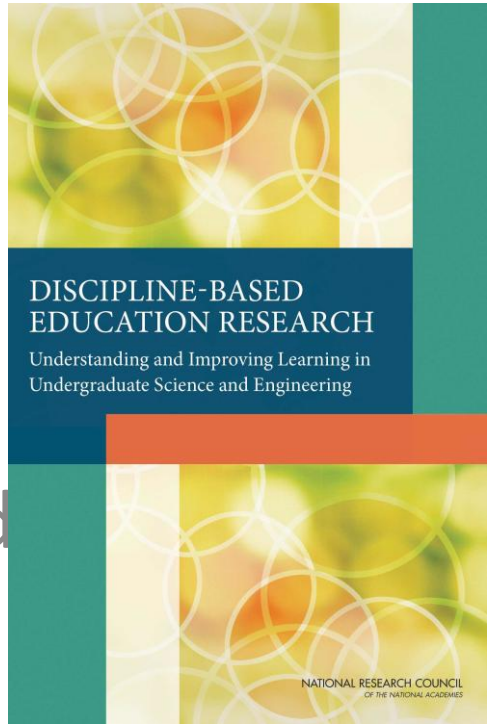
# Discipline-Based Education Research

## Understanding and Improving Learning in Undergrad Science and Engineering

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TRUSE Conference, 2012

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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.*

# Study Charge

1. *What is the state of DBER scholarship as a whole and what currently is being done across each of the natural sciences? Are there research synergies across disciplines?*

2. *What findings are robust across disciplines?*

# Study Charge

3. *What discipline-specific instructional practices are most clearly linked to increased performance across student groups (especially low socio-economic status, minority, and female students)?*

4. *To what extent and how has DBER informed teaching and learning in the various disciplines?*

# Study Charge

5. *What factors are influencing differences in the state of research and its impact in the various disciplines?*

6. *What are the resources, incentives, and conditions needed to advance this research?*

7. *What resources and incentives are needed to ensure that teaching and learning in the various science disciplines is informed by DBER?*

8. *What questions should DBER scholars prioritize in the next generation of research?*

# What is Discipline-Based Education Research?

- *Investigates teaching and learning in discipline using a range of methods with deep grounding in the discipline's priorities, worldview, knowledge, and practices*

- Informed by and complementary to
  - Cognitive science
  - Educational psychology
  - K-12 education research

# Strength of Conclusions

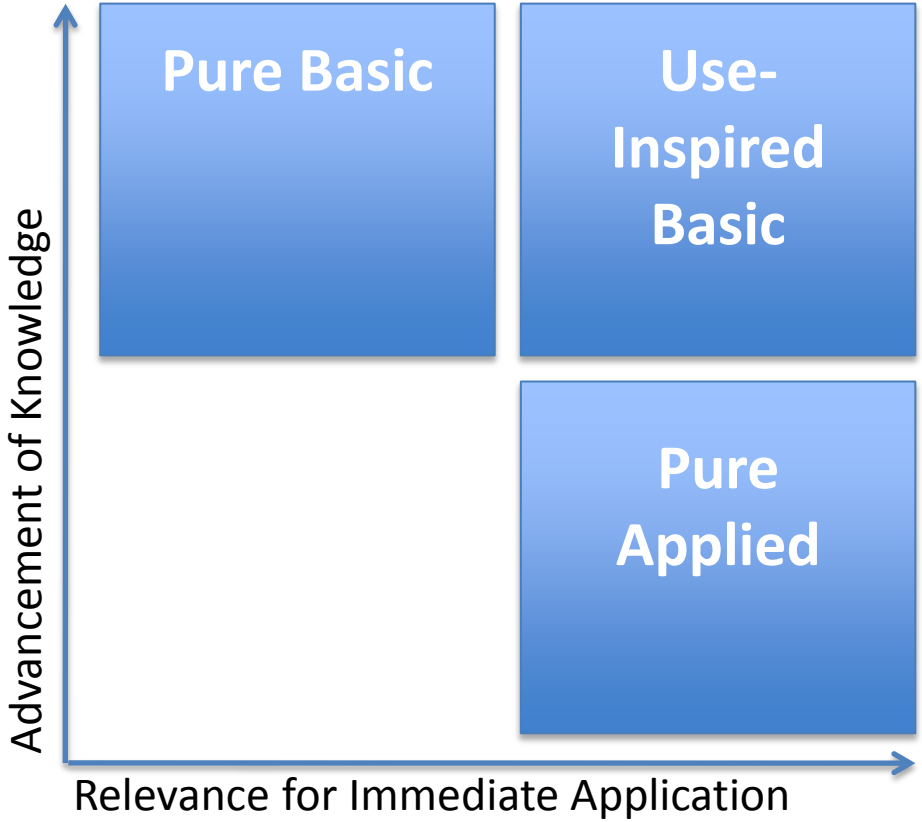
- Limited Evidence
  - Few peer-reviewed studies with some convergence, OR
  - Convergence with practitioner wisdom
- Moderate Evidence
  - Well designed, replicated study, OR
  - Moderate number of small-scale studies, OR
  - A few large-scale studies
- Strong Evidence
  - Numerous well, designed qualitative and/or quantitative studies with high convergence of findings

# 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

# Section I.
# Status of Discipline-Based Education Research

# DBER Designs: Pasteur's Quadrant




Stokes, D.E. (1997). *Pasteur's quadrant: Basic science and technological innovation*. Washington, DC: Brookings Institution Press.

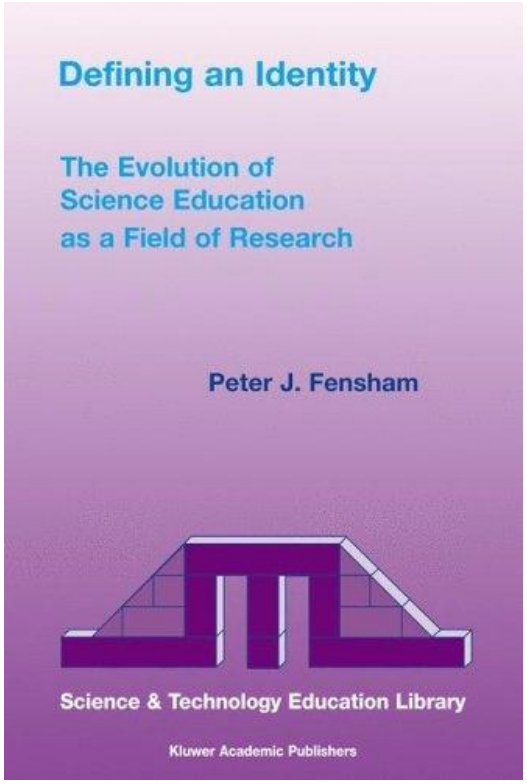
# Goals of DBER

- *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 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.*

# Knowledge Required To Conduct DBER

- Deep, expert disciplinary knowledge
- 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

# Emergence & Current Status of DBER




1. **Structural Criteria**
   a. Academic recognition
   b. Research journals
   c. Professional associations
   d. Research conferences
   e. Research centers
   f. Research training

2. **Intra-Research Criteria**

3. **Outcome Criteria**

Fensham, P.J. (2004). *Defining an identity: The evolution of science education as a field of research.* Boston, MA: Springer.

# Emergence & Current Status of DBER

- Academic recognition
- Research training
  - Graduate Programs
  - Post-docs
  - “Border-crossers”

# Emergence & Current Status of DBER

- Research journals
  - ‘talking research’ vs. ‘talking to practitioner’
  - impact factors
  - standards of evidence for instructional interventions

# Emergence & Current Status of DBER

- Professional associations
- Research conferences
  - RUME, PERC, CERP GRC
  - BER, GER spread across many sub-fields
  - SABER
- Research centers

# Status of DBER: Conclusions

- *DBER is a collection of related research fields rather than a single, unified field. Most efforts to develop and advance DBER are taking place at the level of the individual fields of DBER.*

- *The fields of DBER have made notable progress in establishing venues for publishing and in gaining recognition from their parent disciplines. However DBER scholars still face challenges in identifying pathways for training and professional recognition.*

# Status of DBER: Conclusions

- *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.*

- *Collaborations among the fields of DBER, although relatively limited, have resulted in shared methodology and shared insights into achieving instructional change and building student students' understanding.*

# Section II. Contributions of Discipline-Based Education Research

# Synthesis of the DBER Literature

- Students' conceptual understanding (Ch. 4)
- Problem solving (Ch. 5)
- Use of representations (Ch. 5)
- Effective instructional strategies (Ch. 6)
- Emerging topics (Ch. 7)

# Conceptual Understanding

- *In all disciplines, undergraduate students have incorrect ideas and beliefs about fundamental concepts.*
- *Students have particular difficulties with concepts that involve very large or very small temporal or spatial scales.*

# Problem Solving and 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, such as complex problem solving and domain-specific representations like graphs, models, and simulations. These challenges pose serious impediments to learning in science and engineering, especially if instructors are not aware of them.*

- Expert blindspot

# Research on Effective Instruction

- Several types of research-based curriculum have been shown to promote conceptual change.
- Students can be taught more expert-like problem-solving skills and strategies to improve their understanding of representations.
- Involving students actively in the learning process can enhance learning more effectively than lecturing.
- *The use of learning technology in itself does not improve learning outcomes. Rather, how technology is used matters more.*

# DBER Scope & Research Settings

- Large introductory courses vs. terminal course
- Few upper division or graduate courses
- Challenged by breadth of (sub)disciplines
  - no central “canon” for intro Geoscience course (geology, oceanography, geophysics, geochemistry, atmospheric science, meteorology, climatology, planetary science, physical geography)
  - observational fieldwork (ecology) vs. experimental laboratory (molecular biology)

# Methodological Challenges

- Absence of theoretical frameworks, despite importance in parent disciplines
- Novice-expert continuum
  - *Caveat*: takes 10 years to acquire expertise within a domain
- Independent reproducibility of research findings
- Translate findings into practice

Ericcson, K.A., Krampe, R. Th., and Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, 100(3), 363-406.

# Section III.
# Future Directions
# for
# Discipline-Based
# Education Research

# Research Infrastructure

- *Advancing DBER requires a robust infrastructure for research that includes*
  - *adequate and sustained funding for research and training*
  - *venues for peer-reviewed publication*
  - *recognition and support within professional societies*
  - *professional conferences*

# RECOMMENDATION #1
# Research Infrastructure

- *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*

# RECOMMENDATION #2
# Translating DBER Into Practice

- *With support from institutions, disciplinary departments, and professional societies, faculty should adopt evidence-based teaching practices to improve learning outcomes.*

# RECOMMENDATION #3
# Translating DBER Into Practice

- *To increase the future use of DBER-based teaching approaches, institutions, disciplinary departments, and professional societies should work together to prepare future faculty who understand the findings of research on learning and evidence-based teaching strategies, and who value effective teaching as part of their career aspirations.*

# RECOMMENDATION #4
# Translating DBER Into Practice

- *Institutional leaders should include learning and evidence-based teaching strategies in the professional development of early career faculty, and then include teaching effectiveness in evaluation processes and reward systems through faculty members' careers. Disciplinary societies and the education research communities within them should support these efforts at the national level.*

# Key Elements of a Research Agenda

- Relative effectiveness of different student-centered strategies
- Differential effectiveness
  - Different groups of students
  - Different types of content
- Longitudinal studies
- Additional basic research in DBER

# Key Elements of a Research Agenda

- Outcome measures beyond test scores and course performance
- Better instruments & assessments
- Interdisciplinary studies of cross-cutting concepts and cognitive processes
- Additional research on the translational role of DBER

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