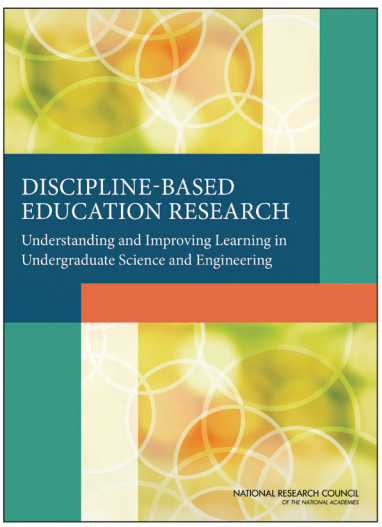
REPORT BRIEF • OCTOBER 2012 BOARD ON SCIENCE EDUCATION

DISCIPLINE-BASED EDUCATION RESEARCH:
UNDERSTANDING AND IMPROVING LEARNING IN UNDERGRADUATE SCIENCE AND ENGINEERING



Preparing a capable workforce and a science-literate citizenry—one able to navigate decisions about health care, energy use, the environment, and other issues—requires effective education in science and engineering. But policy and education leaders have expressed persistent concerns that science and engineering courses are not providing U.S. undergraduates with the high-quality education they need. Moreover, college students drop out of science and engineering majors at higher rates than other majors.

Efforts to improve teaching and learning in science and engineering can be informed by discipline-based education research (DBER). DBER is a field of inquiry emerging in disciplines across academia, including several disciplines of science and engineering. Often motivated by the goal of improving instruction, DBER scholars investigate how people learn the knowledge, concepts, and practices of a particular discipline. A DBER scholar in physics, for example, might investigate how students learn such concepts as force or acceleration and try to identify effective ways for instructors to teach these concepts.

The National Science Foundation asked the National Research Council to convene a committee to consider the status, contributions, and future directions of DBER in undergraduate physics, chemistry, biology, geoscience, and astronomy, as well as in engineering. The committee's findings and recommendations are presented in its report, *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*.

WHAT IS DISCIPLINE-BASED EDUCATION RESEARCH (DBER)?

DBER is not a single research field, but a set of related fields that have emerged in multiple disciplines over several decades. Each field of DBER is tightly coupled to its parent discipline—such as physics, astronomy, or biology—and is chiefly interested in how students learn the concepts and practices of that discipline. However, DBER scholars across all disciplines share similar research approaches and draw on similar theories about learning. And scholars in all DBER fields seek to improve teaching and learning with findings from empirical research.

The long-term goals of DBER are to:

- 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; and
- identify approaches to make science and engineering education broad and inclusive.

KEY FINDINGS FROM DBER

The committee found that important and productive work is happening in DBER, and that DBER scholars have generated findings that hold promise for improving undergraduate science and engineering education. These findings, which have emerged from DBER in many disciplines and which complement findings from research on human learning and cognition, include:

- **Involving undergraduate students actively in the learning process enhances their learning more than traditional lectures**. Examples of effective, research-based approaches include making lectures more interactive, having students work in groups, and incorporating authentic problems and activities.
- **Students have incorrect understandings about fundamental concepts in all disciplines, particularly phenomena that are not directly observable, such as those that involve very large or very small scales of time and space.** For example, students often have difficulty understanding processes that involve deep time, such as Earth's history or natural selection. In addition, many learning challenges in chemistry result from students' difficulties in understanding that matter is made up of discrete particles. DBER in physics has identified instructional techniques that may help—for example, using "bridging analogies" that link students' correct understandings to a situation about which they harbor a misconception.
- **Students are challenged by important aspects of a given domain that can seem easy or obvious to experts.** In problem solving, for example, students tend to focus on the superficial aspects of a problem rather than its deep structure. Students in all disciplines also have trouble understanding 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. Several strategies appear to improve problem-solving skills, such as providing support and prompts—known as "scaffolding"—as students work their way through problems.

INCREASING USE OF DBER FINDINGS

Discipline-based education research has not yet prompted widespread changes in teaching practice among undergraduate faculty in science and engineering, despite its potential to do so. To improve learning outcomes for their students, current faculty in science and engineering should adopt teaching strategies that research has shown to be effective. Institutions, disciplinary departments, and professional societies interested in improving undergraduate education should support faculty efforts to do so.

In addition, these institutions and groups should work together to prepare future faculty, helping them understand the findings of research on effective teaching strategies and how students learn. Institutional leaders should include evidence-based teaching strategies in the professional development of early-career faculty, and they should include teaching effectiveness in evaluation processes and reward systems throughout faculty members' careers.

However, changing the teaching practices of large numbers of undergraduate faculty will not be easy. Simply informing faculty of evidence-based approaches does not seem to produce changes in teaching practices. Efforts to translate DBER into practice are more likely to succeed if they 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 teaching practice. Faculty are unlikely to change their teach-

ing approaches without opportunities to reflect on their own teaching practice, compare their practice to more-effective research-based approaches, and decide on their own to adopt new practices.

FUTURE DIRECTIONS FOR RESEARCH

Future studies in DBER fields are needed to gain a better understanding of:

- **Whether and how students' learning and response to different instructional approaches varies by key characteristics.** Those characteristics include gender, ethnicity, socioeconomic status, and whether or not they are majoring in the field.
- **Students' learning in a wide variety of undergraduate course settings.** Existing DBER provides excellent insights into students' understanding of introductory course material, but less is known about learning in upper-division courses or in laboratory and field settings.
- **Students' learning over time.** Longitudinal studies would enhance understanding of how students' knowledge transfers (or fails to transfer) from one setting to another. Such studies could also shed light on how and why incorrect beliefs persist or re-emerge over time, and why students either persist in or depart from science and engineering majors.
- **More nuanced aspects of instruction.** Research has demonstrated that student-centered learning can be more effective than traditional lecture. Now, DBER should be expanded to identify teaching techniques that can, for example, promote conceptual change in students, help them use visualizations and solve problems, and improve their metacognition (awareness of their own learning process and when to shift learning strategies).
- **Concepts and cognitive processes that cut across disciplines.** In addition to discipline-specific questions, cross-cutting concepts—such as energy or systems—and concepts that students have difficulty understanding in many disciplines (such as concepts that involve very small or large scales of measurement, or deep time) also merit research attention.
- **The translational role of DBER.** To achieve the goal of increasing the use of DBER in teaching practice, some scholarship needs to focus on organizational and faculty behavioral change.

ADVANCING DBER AS A RESEARCH FIELD

DBER scholars have made notable inroads in establishing venues for publishing and in gaining recognition from their parent disciplines. Each field of DBER has one or more professional organizations that support education research through policy statements, publications, and conferences, and all of the DBER fields have at least one peer-reviewed journal for their work. Despite this progress, DBER scholars still face challenges. For example, becoming established in a new and interdisciplinary research field such as DBER is time consuming and not straightforward, and so early-career faculty members may not appear as productive to tenure committees.

As an emerging field, DBER now needs:

- **A robust infrastructure for research that includes adequate and sustained funding for research and training.** Currently, funding across the fields of DBER is uneven. Adequate support to enable the growth of DBER includes funding for the research identified above, training for future DBER scholars, support for ongoing professional development for active faculty, and funding for initiatives designed to translate DBER findings into practice.
- **Venues for peer-reviewed publication.** The number of venues for publishing empirical research has expanded as the DBER fields have matured, though the journals vary in their standards for research.
- **Continued recognition and support within professional societies.** The fields of DBER have all been recognized by professional societies in the parent disciplines as valid and important fields of research; continued support is important for advancing research and attracting scholars to the specialty.
- **Additional venues where DBER scholars can share their research findings**; some professional conferences have already emerged.

COMMITTEE ON THE STATUS, CONTRIBUTIONS, AND FUTURE DIRECTIONS OF DISCIPLINE-BASED EDUCATION RESEARCH

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For More Information . . .

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