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#### “What if students revolt?”—Considering Student Resistance: Origins, Options, and Opportunities for Investigation

Shannon B. Seidel and Kimberly D. Tanner . . . . . 586–595

Instructors attempting new teaching methods may have concerns that students will resist nontraditional teaching methods. The authors provide an overview of research characterizing the nature of student resistance and exploring its origins. Additionally, they provide potential strategies for avoiding or addressing resistance and pose questions about resistance that may be ripe for research study.

### From the National Academies

#### Engaging Actively with Issues in the Responsible Conduct of Science: Lessons from International Efforts Are Relevant for Undergraduate Education in the United States

John D. Clements, Nancy D. Connell, Clarissa Dirks, Mohamed El-Faham, Alastair Hay, Elizabeth Heitman, James H. Stith, Enriqueta C. Bond, Rita R. Colwell, Lida Anestidou, Jo L. Husbands, and Jay B. Labov . . . . . 596–603

This Feature describes a National Research Council project centered on educating faculty in the Middle East/North Africa and Asia to use active learning when teaching responsible conduct of science (RCS). It provides insights for faculty in the United States as they engage students in the intricacies of RCS or establish “train-the-trainer” programs at their home institutions.

### Book Review

#### Denying Genetic Causality

Karen G. Hales . . . . . 604–605

This edited volume of essays presents a countermainstream view against genetic underpinnings for cancer, behavior, and psychiatric conditions.

## RESEARCH METHODS

### Best Practices for Measuring Students’ Attitudes toward Learning Science

Matthew Lovelace and Peggy Brickman . . . . . 606–617

This review presents an overview of some of the common assessment tools available to measure students’ attitudes toward learning science. The review also provides widely endorsed, straightforward recommendations for analysis methods with theory and empirical evidence to support analysis plans.

## ARTICLES

### **The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices**

Michelle K. Smith, Francis H. M. Jones, Sarah L. Gilbert, and Carl E. Wieman . . . . . 618–627

To help institutions collect information on undergraduate teaching practices, the authors developed a new classroom observation protocol known as the Classroom Observation Protocol for Undergraduate STEM (COPUS). This protocol allows college science, technology, engineering, and mathematics faculty, after a short training period, to reliably characterize how faculty and students are spending their time in class.

### **Development of the Biology Card Sorting Task to Measure Conceptual Expertise in Biology**

Julia I. Smith, Elijah D. Combs, Paul H. Nagami, Valerie M. Alto, Henry G. Goh, Muryam A. A. Gourdet, Christina M. Hough, Ashley E. Nickell, Adrian G. Peer, John D. Coley, and Kimberly D. Tanner . . . . . 628–644

The authors present the development of a novel assessment tool, the Biology Card Sorting Task, designed to probe how individuals organize their conceptual knowledge of biology. Results suggest that the task is robust in distinguishing populations of biology experts and novices and represents a useful tool for probing emerging biology conceptual expertise.

### **Understanding Clicker Discussions: Student Reasoning and the Impact of Instructional Cues**

Jennifer K. Knight, Sarah B. Wise, and Katelyn M. Southard . . . . . 645–654

This paper characterizes in-class discussion of clicker questions among upper-level biology majors, demonstrating that students exchanged ideas in 75% of the recorded clicker discussions, using high-quality reasoning almost 50% of the time. In addition, when cued by the instructor to use reasoning, they engaged in higher-quality discussions.

### **Development of a Meiosis Concept Inventory**

Pamela Kalas, Angie O’Neill, Carol Pollock, and Gülnur Birol . . . . . 655–664

A 17-question Meiosis Concept Inventory (Meiosis CI) was designed, developed, and validated to diagnose student misconceptions on meiosis, a fundamental concept in genetics. The Meiosis CI targets large introductory biology and genetics courses.

### **The EvoDevoCI: A Concept Inventory for Gauging Students’ Understanding of Evolutionary Developmental Biology**

Kathryn E. Perez, Anna Hiatt, Gregory K. Davis, Caleb Trujillo, Donald P. French, Mark Terry, and Rebecca M. Price . . . . . 665–675

The authors present the development and validation of the EvoDevoCI, a concept inventory for evolutionary developmental biology. This CI measures student understanding of six core evolutionary developmental biology (evo-devo) concepts using four scenarios and 11 multiple-choice items, all inspired by authentic scientific examples. Distracters were designed to represent the common conceptual difficulties students have with each evo-devo concept.

### **A Deliberate Practice Approach to Teaching Phylogenetic Analysis**

F. Collin Hobbs, Daniel J. Johnson, and Katherine D. Kearns . . . . . 676–686

The authors implemented a deliberate practice approach to engage students over the course of a semester in a series of increasingly complex hands-on tasks related to phylogenetic tree construction. Final exam scores, pre- and postconcept surveys, and student feedback support that the approach improved student comprehension of this difficult subject.

### **Engagement and Skill Development in Biology Students through Analysis of Art**

Liliana Milkova, Colette Crossman, Stephanie Wiles, and Taylor Allen . . . . . 687–700

This work describes implementation and assessment of an art-based activity that piques undergraduates’ curiosity, broadens the ways in which students meaningfully engage with course content and concepts related to human biology, and develops aspects of students’ higher-level thinking skills, such as analysis, synthesis, and evaluation.

**Lessons Learned from Undergraduate Students in Designing a Science-Based Course in Bioethics**  
John D. Loike, Brittany S. Rush, Adam Schweber, and Ruth L. Fischbach . . . . . 701–710

We present an analysis of students’ approaches for identifying, resolving, managing, and/or defusing bioethical issues as applied in the design of a science-based course in bioethics.

**What Do I Want to Be with My PhD? The Roles of Personal Values and Structural Dynamics in Shaping the Career Interests of Recent Biomedical Science PhD Graduates**  
Kenneth D. Gibbs, Jr., and Kimberly A. Griffin . . . . . 711–723

This paper addresses the process of career-interest formation as it relates to faculty careers in a diverse cohort of 38 recent biomedical sciences PhD graduates (including 23 women and 18 underrepresented minorities). The authors show that personal values and structural dynamics in the biomedical workforce play strong roles in shaping career interest.

*On the Cover*

The Biology Card Sorting Task is designed to probe how individuals’ conceptual knowledge of biology is organized. Modeled on similar tasks developed in cognitive psychology, the task is designed to test two hypothesized organizations: 1) a surface feature organization focused on organism type and 2) a deep feature organization focused on fundamental biological concepts. Sixteen biology problems were selected for this task. The upper left image depicts a hypothesized card sort based on deep features of the problems that might be expected from a biological expert. The lower right image depicts a hypothesized sort based on surface features of the problems that might be expected from a biological novice. Identifying letter colors in the images correspond to the following deep features: green for evolution, blue for structure–function, purple for information flow, and red for transformations of energy and matter. Cards used in the research study (see p. 628) contained only black lettering, and the identifying letter on each card was less prominent. (Photo credit: Paul Asper, San Francisco State University)