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### SPECIAL ISSUE ON CROSS-DISCIPLINARY RESEARCH IN BIOLOGY EDUCATION

#### EDITORIAL

##### **Cross-Disciplinary Research in Biology Education: Challenges and Opportunities**

*Ido Davidesco and Kimberly D. Tanner*

#### APPROACHES TO BIOLOGY TEACHING AND LEARNING

##### **Attention Matters: How Orchestrating Attention May Relate To Classroom Learning**

*Arielle S. Keller, Ido Davidesco, and Kimberly D. Tanner*

Attention is the gateway between information and learning, yet there is much we do not know about how instructors orchestrate attention in classrooms. A framework is presented for understanding attention in the classroom to explore how different approaches to the same active-learning strategy might vary in how effectively they direct attention.

#### CURRENT INSIGHTS

##### **Recent Research in Science Teaching and Learning**

*Sarah L. Eddy*

This installment of *Current Insights* features three studies drawing on psychology and learning sciences that help us understand how to increase student motivation to engage in scientific writing, how drawing can enhance learning, and whether spacing, or distributed practice, matters in actual classes.

#### ESSAYS

##### **Transfer: A Review for Biology and the Life Sciences**

*Althea N. Kaminske, Carolina E. Kuepper-Tetzel, Cynthia L. Nebel, Megan A. Sumeracki, and Sean P. Ryan*

Transfer of knowledge from one context to another is crucial in education, but difficult for students to achieve. This review discusses how different factors such as learner abilities, taught material, and lesson characteristics affect transfer performance in biology and life sciences education and offers practical advice for teachers.

##### **Leveraging Psychosocial Interventions to Motivate Instructor Participation in Teaching Professional Development**

*Lisa B. Limeri, Miranda M. Chen Musgrove, Meredith A. Henry, and Elisabeth E. Schussler*

Teaching professional development (TPD) efforts to reform undergraduate education will not meet their goals if instructors are not motivated to attend. Research on psychosocial interventions could be leveraged to design interventions that will increase instructors' motivation to attend TPD.

### **Brain-to-Brain Synchrony in the STEM Classroom**

*Ido Davidesco*

Recent advances in portable electroencephalography (EEG) now allow researchers to collect brain data from groups of students in real-world classrooms. This *Essay* highlights how this emerging line of research can open new opportunities for collaboration between discipline-based education researchers and cognitive and social neuroscientists.

### **Design-Based Research: A Methodology to Extend and Enrich Biology Education Research**

*Emily E. Scott, Mary Pat Wenderoth, and Jennifer H. Doherty*

Design-based research from the learning sciences is a compelling methodology for investigating the mechanisms by which students develop sophisticated ideas about biology. It fosters research collaborations across disciplines, develops and tests theory-based instructional tools, and draws on mixed methods to examine how students learn.

## **ARTICLES**

### **Representing Variability: The Case of Life Cycle Diagrams**

*David Menendez, Olympia N. Mathiapparanam, David Liu, Vienne Seitz, Martha W. Alibali, and Karl S. Rosengren*

An examination of life cycle diagrams from books and from an online database of science diagrams is presented. Many diagrams contained many irrelevant details, depicted the life cycle as a closed circle, and did not depict any form of biological variability. How these features might influence student learning and biological reasoning is discussed.

### **Using Students' Concept-Building Tendencies to Better Characterize Average-Performing Student Learning and Problem-Solving Approaches in General Chemistry**

*Regina F. Frey, Mark A. McDaniel, Diane M. Bunce, Michael J. Cahill, and Martin D. Perry*

Students' concept-building approaches (abstraction vs. exemplar), identified a priori with a cognitive-psychology laboratory task, have been extended to learning complex topics in general chemistry. Here, the effect concept-building approaches have on the problem-solving behaviors of average-achieving students was probed via think-aloud interviews.

### **Using Framing as a Lens to Understand Context Effects on Expert Reasoning**

*Tara Slominski, Andrew Fugleberg, Warren M. Christensen, John B. Buncher, and Jennifer L. Momsen*

Biologists frame fluid dynamics problems differently from physicists and engineers, which may have consequences for instruction and learning.

### **Test-Enhanced Learning and Incentives in Biology Education**

*Bryn St. Clair, Paul Putnam, Harold L. Miller, Ross Larsen, and Jamie L. Jensen*

This study examined the testing effect in a postsecondary biology course with low- and high-incentive treatments and measured student learning. Although exposure to exams predicted better learning, incentive level did not moderate this effect, an outcome that contradicted recent laboratory findings that higher incentives decreased the testing effect.

### **Testing Effect on High Level Cognitive Skills**

*Jamie L. Jensen, Mark A. McDaniel, Tyler A. Kummer, Patricia D. D. M. Godoy, and Bryn St. Clair*

This authentic classroom application of the testing effect, a robust learning technique, demonstrates that the testing effect applies to high-level items; does not extend to increased low-level content knowledge; and potentially indicates a three-part mechanism, including content, skill, and the ability to make the connection.

### **Optimizing the Efficacy of Learning Objectives Through Pretests**

*Faria Sana, Noah D. Forrin, Mrinalini Sharma, Tamara Dubljevic, Peter Ho, Ezza Jalil, and Joseph A. Kim*

The inclusion of learning objectives at the beginning of a lesson is widely adopted in science education, but do they improve learning? Three controlled lab studies systematically explore how learning objectives can be optimized to lead to learning gains.

### **Mindset, Motivation, and Teaching Practice: Psychology Applied to Understanding Teaching and Learning in STEM Disciplines**

*Deborah South Richardson, Robert S. Bledsoe, and Zaraly Cortez*

This article reports a study of the relationships among instructor mindset, attitudes about motivation (mastery orientation), and effective teaching practices. Mastery orientation mediates the relationship between mindset and teaching behavior, providing support for Dweck's model of implicit theories of personality and motivation.

### **Simulating a Computational Biological Model, Rather than Reading, Elicits Changes in Brain Activity During Biological Reasoning**

*Caron A. C. Clark, Tomáš Helikar, and Joseph Thomas Dauer*

Undergraduates who computationally simulated a biological model showed increased activity in occipital and parietal brain regions when later reasoning about that model relative to students who learned through reading. Accuracy in model-based reasoning correlated with prefrontal brain activity.

### **Learning Analytics to Assess Beliefs about Science: Evolution of Expertise as Seen Through Biological Inquiry**

*Melanie E. Pepper, Niloofar Ramezani, David Quigley, Emily Royse, and Chloe Bruce*

This work leverages methods from the learning analytics community to create an assessment of epistemological beliefs about science as seen through inquiry practices. Results advance our understanding of how to assess cognitive constructs through practices and the development of epistemological beliefs over the course of becoming a biologist.

### **Value of Case-Based Learning within STEM Courses: Is it the Method or is it the Student?**

*Ashley Rhodes, Abigail Wilson, and Timothy Rozell*

This study explores the relationship between the benefits of case-based learning and specific student characteristics such as prior knowledge of subject material and number of college credit hours completed.

### **Advancing the Guidance Debate: Lessons from Educational Psychology and Implications for Biochemistry Learning**

*Stephanie M. Halmo, Cheryl A. Sensibaugh, Peter Reinhart, Oleksandra Stogniy, Logan Fiorella, and Paula P. Lemons*

This study compares the impacts on biochemistry student learning for three evidence-based pedagogies—worked examples plus practice, productive failure, and guided inquiry—that differ in the nature and timing of guidance.

## **GENERAL ESSAYS AND ARTICLES**

### **ESSAYS**

#### **Applying Experiential Learning to Career Development Training for Biomedical Graduate Students and Postdocs: Perspectives on Program Development and Design**

*Audra Van Wart, Theresa C. O'Brien, Susi Varvayanis, Janet Alder, Jennifer Greenier, Rebekah L. Layton, C. Abigail Stayart, Inge Wefes, and Ashley E. Brady*

Four types of experiential learning approaches used for predoctoral graduate students and postdoctoral scholars in the biomedical sciences are described and associated learning objectives and evaluation strategies are compared. This framework will help other institutions design and deliver experiential learning programs for career training.

### **Fourteen Recommendations to Create a More Inclusive Environment for LGBTQ+ Individuals in Academic Biology**

*Katelyn M. Cooper, Anna Jo J. Auerbach, Jordan D. Bader, Amy S. Beadles-Bohling, Jacqueline A. Brashears, Erica Cline, Sarah L. Eddy, Deanna B. Elliott, Elijah Farley, Linda Fuselier, Heather M. Heinz, Madison Irving, Tanya Josek, A. Kelly Lane, Stanley M. Lo, Jeffrey Maloy, Michelle Nugent, Erika Offerdahl, Juan Palacios-Moreno, Jorge Ramos, Joshua W. Reid, Rachel A. Sparks, Ashley L. Waring, Mike Wilton, Cara Gormally, and Sara E. Brownell*

This essay highlights recommendations to make academic biology more inclusive of LGBTQ+ individuals. These recommendations are drawn from the literature and the collective experience of the 26-member author team.

### **“How Well Does Your Structural Equation Model Fit Your Data?”: Is Marcoulides and Yuan’s Equivalence Test the Answer?**

*James Peugh and David F. Feldon*

Marcoulides and Yuan have introduced an equivalence test to assess structural equation model fit as an inferential alternative to Hu and Bentler’s descriptive cut-points. A procedural demonstration of how to conduct and interpret an equivalence model fit test, concluding caveats, and future research possibilities are offered.

## **ARTICLES**

### **From Theory to Practice: Gathering Evidence for the Validity of Data Collected with the Interdisciplinary Science Rubric (IDSR)**

*Brie Tripp and Erin E. Shortlidge*

This study developed a new instrument, the Interdisciplinary Science Rubric, or IDSR, to measure undergraduate students’ interdisciplinary science thinking. Evidence of reliability and validity was established on the constructs and criteria of the rubric, resulting in an instrument that accurately assesses this competency.

### **College Student Conceptions about Changes to Earth and Life over Time**

*Patricia Jaimes, Julie C. Libarkin, and Dominik Conrad*

This study focuses on college student conceptions of scientific concepts at the intersection of the biosciences and geosciences across two different populations (U.S. and Germany). Findings highlight the need for scientific education instruction in both countries that is interdisciplinary in content.

### **Student Pre-Class Preparation by Both Reading the Textbook and Watching Videos Online Improves Exam Performance in a Partially Flipped Course**

*Kaleb Bassett, Gayla R. Olbricht, and Katie B. Shannon*

For a flipped course, it is critical that students prepare before class. Instead of showing a marked preference for watching videos, most students both watched videos and read the textbook. Both types of preparation positively correlate with exam grades, and multivariate analysis was used to generate a predictive model of student exam performance.

### **The Effect of a Paired Lab on Course Completion and Grades in Non-Majors Introductory Biology**

*Dayna Jean DeFeo, Andrew Bibler, and Sarah Gerken*

Students who take introductory biology labs have better lecture course outcomes than students who do not take a lab. However, this analysis finds that much of the difference in student performance is attributable to selection bias rather than the lab itself. The data challenge the misconception that labs serve as recitations for lecture content.

### **Highlighting Prosocial Affordances of Science in Textbooks to Promote Science Interest**

*Jeanette Zambrano, Garam Ann Lee, Christina C. Leal, and Dustin B. Thoman*

Science stereotypes include robust beliefs that science fields lack opportunities to fulfill prosocial goals. These beliefs reduce student interest in science—especially for racial/ethnic minorities. Highlighting the prosocial utility value of science in textbooks can change these beliefs to promote undergraduate student interest.

### **Female In-Class Participation and Performance Increase with More Female Peers and/or a Female Instructor in Life Sciences Courses**

*E. G. Bailey, R. F. Greenall, D. M. Baek, C. Morris, N. Nelson, T. M. Quirante, N. S. Rice, S. Rose, and K. R. Williams*

Female students are less likely to participate in class than male peers in life sciences courses of all levels, but they are more likely to participate in classrooms with more female peers. Female students earn lower final course grades than males in classes taught by a male instructor and/or when female students are in the minority.

### **Students Understanding of the Dynamic Nature of Genetics: Characterizing Undergraduates' Explanations for Interaction Between Genetics and Environment**

*Michal Haskel-Ittah, Ravit Golan Duncan, and Anat Yarden*

This research investigates how students reason about the phenomenon of phenotypic plasticity. An analysis of student interviews revealed two types of mechanistic explanations, one of which seems to be less intuitive but is critical for reasoning about core biological ideas such as homeostasis and development.

### **Concept Map Assessment Reveals Short-Term Community-Engaged Fieldwork Enhances Sustainability Knowledge**

*Jessica L. Pruett and Emily G. Weigel*

Student-generated concept maps in an undergraduate ecology laboratory course were used to examine the benefit of community-engaged fieldwork on sustainability learning. This short-term service-learning experience led to conceptual changes in sustainability knowledge and is a promising pedagogical approach in sustainability education.

### **Evaluation of a Questionnaire Measuring University Students' Sense of Belonging to and Involvement in a Biology Department**

*Eva Knekta, Kyriaki Chatzikyriakidou, and Melissa McCartney*

The article presents an instrument measuring university students' sense of belonging to and involvement in their "home" department (biology), as well as initial validity evidence supporting the proposed use of the instrument.

### **A Hierarchical Mentoring Program Increases Confidence and Effectiveness in Data Analysis and Interpretation for Undergraduate Biology Students**

*Cascade J. B. Sorte, Nancy M. Aguilar-Roca, Amy K. Henry, and Jessica D. Pratt*

A hierarchical mentoring program incorporated into an upper-level ecology course led to improvements in perceived and demonstrated ability in data analysis and interpretation. Such a program contributes to career readiness by building core competencies in critical thinking and science communication.

### **Mentoring Structures and the Types of Support Provided to Early-Year Undergraduate Researchers**

*Gaye D. Ceyhan and John W. Tillotson*

This study investigated undergraduate researchers' perspectives on mentoring structures and the support provided to them in their first and sophomore years. Participants reported receiving different types of support from faculty and postgraduates depending on their mentoring structures and the amount of research experience they gained.

### **Finding a Fit: Biological Science Doctoral Students' Selection of a Principal Investigator and Research Laboratory**

*Michelle A. Maher, Annie M. Wofford, Josipa Roksa, and David F. Feldon*

This study explored how biological science doctoral students made decisions about fitting with a principal investigator (PI) and within a research lab. Results illuminated a complex array of factors students considered in selecting a PI, including PI mentoring style and professional stability. Peers and research projects played an important role in students' lab selection.

### **Self-Efficacy and Performance of Research Skills Among First-Semester Bioscience Doctoral Students**

*Katherine Lachance, Ronald J. Heustis, Joseph J. Loparo, and Madhvi J. Venkatesh*

Incoming doctoral students have gaps in research skills that are not correlated with duration of prior research experience. During their first semester of training, most students improve in both research skills self-efficacy and experimental design performance. They attribute changes to many factors, including research, course work, and mentoring.

### **Navigating Tensions of Research and Teaching: Biology Graduate Students' Perceptions of the Research-Teaching Nexus within Ecological Contexts**

*Joshua W. Reid and Grant E. Gardner*

This article presents data from a cross-sectional study on biology graduate students' perceptions of the research-teaching nexus (RTN). Findings indicate that the majority of biology graduate students hold synergistic views of the RTN but receive mixed messages about this relationship from others.

### **The ASPET Mentoring Network: Enhancing Diversity and Inclusion through Career Coaching Groups within a Scientific Society**

*Veronica Y. Womack, Bhoomi K. Thakore, Christine V. Wood, David C. Jewett, Remi F. Jones, Susan L. Ingram, Janet A. Clark, Catherine L. Fry, Lynn Wecker, and Richard McGee*

The American Society for Pharmacology and Experimental Therapeutics (ASPET) Mentoring Network, career mentoring groups of six PhD students and postdocs, begin with an in-person meeting the day before the ASPET annual meeting. Led by an experienced ASPET member, each group then meets virtually for a year. Evaluation data from the first three cohorts provide strong evidence of perceived and real benefits of the groups.

### **Disciplinary Bias, Money Matters, and Persistence: Dean Perspectives on Science Faculty with Education Specialties (SFES)**

*Seth D. Bush, Michael T. Stevens, Kimberly D. Tanner, and Kathy S. Williams*

While science faculty with education specialties (SFES) have been well described, the perspectives of academic leaders on SFES have not been systematically studied. The perspectives of college of science deans from the largest university system in the United States that highlight SFES persistence despite biases against science education are presented here.

### **CORRECTION**

#### **Applying Graph Theory to Examine the Dynamics of Student Discussions in Small-Group Learning**

*Albert Chai, Joshua P. Le, Andrew S. Lee, and Stanley M. Lo*

#### *On the Cover*

Sumana Sundaramurthy, Co-Submitted by David Pruyne. Movement of screw-propelled worms! 2nd place image. 2019 ASCB Green Fluorescent Protein Competition.