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LETTER TO THE EDITOR

Set Theory, Logic, and Probability: The Integration of Qualitative Reasoning into Teaching Statistics for Quantitative Biology

Chenshu Liu and Ruijun Zhu

BOOK REVIEWS

Systems Biology for 21st-Century Quantitative Scientists

Dietlind L. Gerloff and Jonghoon Kang

This is a review of a unique biology textbook recently published by a renowned scientist, Philip Nelson. In our view, this excellent book will appeal to both students and professional scientists in the field of quantitative biology.

Helping Teachers in the Evolution-Teaching Dilemma: *Understanding Evolution* by Kostas Kampourakis

Lisa K. Elfring

Kostas Kampourakis's *Understanding Evolution* is a resource for teachers who want to understand why evolution is a difficult topic.

A Resource of Resources for STEM Educators

Cheryl A. Sensibaugh

This is a review of *Teaching and Learning STEM: A Practical Guide*, which goes beyond active-learning techniques into the realms of course design, facilitating skill development, and assessment. This superb resource compiles a plethora of empirical evidence, while unpacking it in a way that is immediately accessible to educators across disciplines.

MEETING REPORT

Summit of the Research Coordination Networks for Undergraduate Biology Education

Carrie Diaz Eaton, Deborah Allen, Laurel J. Anderson, Gillian Bowser, Mark A. Pauley, Kathy S. Williams, and Gordon E. Uno

This report highlights the discussions and recommendations featured at the first summit meeting of projects funded by the National Science Foundation's Research Coordination Networks for Undergraduate Biology Education program, held January 14–16, 2016, in Washington, DC.

WWW.LIFE SCIENCES EDUCATION

Online Teaching Resources about Medicinal Plants and Ethnobotany

Kristina M. Straus and Eric H. Chudler

Classroom exploration of plant-based medicines and ethnobotany is a timely and valuable way to engage students in science. This *Feature* highlights Internet-based resources to help teachers in primary and secondary classrooms incorporate lessons and activities to teach about plant medicines.

RESEARCH METHODS

Mixed-Methods Design in Biology Education Research: Approach and Uses

Abdi-Rizak M. Warfa

This article provides a practical “how-to” guide on mixed-methods research (MMR) for biology education research (BER) studies that use quantitative and qualitative methods. Using biology-friendly analogies and illustrative BER studies, the paper describes factors that influence methodological choices in MMR and appropriate strategies for choosing relevant designs.

Rasch Analysis for Instrument Development: Why, When, and How?

William J. Boone

Rasch psychometric techniques can be used to guide the development and analysis of tests and surveys. Rasch techniques also can be used to explain the meaning of a test score or survey score. Of great interest to researchers and instructors is that Rasch techniques allow different forms of a test to be developed.

ESSAYS

Effective Educational Videos: Principles and Guidelines for Maximizing Student Learning from Video Content

Cynthia J. Brame

Educational videos provide an important content-delivery tool in many classes. Effective use of video is enhanced when instructors consider cognitive load, student engagement, and active learning. This essay reviews literature relevant to these elements and suggests practical ways instructors can use these principles when using video as an educational tool.

Crossing the Threshold: Bringing Biological Variation to the Foreground

Janet M. Batzli, Jennifer K. Knight, Laurel M. Hartley, April Cordero Maskiewicz, and Elizabeth A. Desy

This essay summarizes the authors’ study of, conversations about, and thought processes on threshold concepts. Using biological variation as an example, the authors demonstrate the utility of threshold concepts for curriculum development and research on student learning.

Encouragement for Faculty to Implement *Vision and Change*

Caylyn Harvey, Kristen Eshleman, Kyosung Koo, Kevin G. Smith, Christopher J. Paradise, and A. Malcolm Campbell

A two-semester introductory biology course that incorporates the recommendations of *Vision and Change* is described. The course has been well received by students and produced good student learning outcomes. This essay demonstrates that *Vision and Change*’s recommendations are feasible and students welcome the improvements.

STEM Faculty as Learners in Pedagogical Reform and the Role of Research Articles as Professional Development Opportunities

Amy B. Mulnix

Learning theory can be applied to faculty in the process of pedagogical reform. Discipline-based education research publications better serve reform when they integrate learning principles in form and content.

The College Science Learning Cycle: An Instructional Model for Reformed Teaching

Michelle Withers

This paper introduces a College Science Learning Cycle adapted from the popular Biological Sciences Curriculum Study 5E to help science, technology, engineering, and mathematics faculty develop course materials to support active, student-centered teaching approaches in their classrooms.

Practical Strategies for Collaboration across Discipline-Based Education Research and the Learning Sciences

Melanie Peffer and Maggie Renken

As the field of discipline-based education research continues to grow and enters into its “second generation,” this essay provides timely and useful advice for advancing life sciences education research and provides practical strategies for collaborations across the life and learning sciences.

A Guide for Graduate Students Interested in Postdoctoral Positions in Biology Education Research

Melissa L. Aikens, Lisa A. Corwin, Tessa C. Andrews, Brian A. Couch, Sarah L. Eddy, Lisa McDonnell, and Gloriana Trujillo

Intended as a resource for life sciences graduate students, this essay discusses the diversity of postdoctoral positions in biology education and the careers to which they lead. The authors also provide advice to help graduate students develop the skills necessary to obtain a biology education research postdoctoral position.

ARTICLES

Student Buy-In to Active Learning in a College Science Course

Andrew J. Cavanagh, Oriana R. Aragón, Xinnian Chen, Brian A. Couch, Mary F. Durham, Aiyana Bobrownicki, David I. Hanauer, and Mark J. Graham

Student buy-in as a key mechanism for student engagement and performance in an active-learning context is explored. This paper provides the first operational definition of student buy-in to in-class activities, in this case characterizing the complex nature of students’ responses in an active-learning classroom.

Characterizing Student Perceptions of and Buy-In toward Common Formative Assessment Techniques

Kathleen R. Brazeal, Tanya L. Brown, and Brian A. Couch

Formative assessments aim to promote learning by developing a cycle in which students demonstrate their understanding and receive feedback. This mixed-methods study sought to identify the degree to which students perceive various in-class and out-of-class activities as accomplishing key objectives of formative assessment.

Does the Room Matter? Active Learning in Traditional and Enhanced Lecture Spaces

Jon R. Stoltzfus and Julie Libarkin

This study compares student perceptions and performance in a SCALE-UP–type instructional space with those in a traditional lecture hall. Flipped instruction relying heavily on cooperative learning was used in both spaces. Student learning was measured using a validated assessment instrument.

Collaborative Learning in Higher Education: Evoking Positive Interdependence

Karin Scager, Johannes Boonstra, Ton Peeters, Jonne Vulperhorst, and Fred Wiegant

This study focuses on factors increasing the effectiveness of collaborative learning. Results show that challenging, open, and complex group tasks that required the students to create something new and original evoked effective collaboration.

Group Random Call Can Positively Affect Student In-Class Clicker Discussions

Jennifer K. Knight, Sarah B. Wise, and Scott Sieke

This study explored how using in-class accountability affects the nature of students’ clicker question discussions. A higher proportion of discussions in the random call condition contained exchanges of reasoning and some forms of questioning compared with discussion in the volunteer call condition, thus suggesting positive impacts of random calling.

A Measure of College Student Persistence in the Sciences (PITS)

David I. Hanauer, Mark J. Graham, and Graham F. Hatfull

This paper validates and establishes the predictive ability of the Persistence in the Sciences, or PITS, survey to measure persistence in undergraduates participating in course-based research experiences.

Step by Step: Biology Undergraduates' Problem-Solving Procedures during Multiple-Choice Assessment

Luanna B. Prevost and Paula P. Lemons

Findings from a mixed-methods investigation of undergraduate biology problem solving are reported. Students used a variety of problem-solving procedures that are domain general and domain specific. This study provides a model for research on alternative problem types and can be applied immediately in the biology classroom.

Fostering 21st-Century Evolutionary Reasoning: Teaching Tree Thinking to Introductory Biology Students

Laura R. Novick and Kefyn M. Catley

The ability to interpret and reason from Tree of Life diagrams is a vital aspect of 21st-century science literacy. This article reports the development, implementation, and evaluation of a research-based curriculum (an instructional booklet, lectures, and laboratory) to teach such tree thinking in an undergraduate biology class for science majors.

Using Student Writing and Lexical Analysis to Reveal Student Thinking about the Role of Stop Codons in the Central Dogma

Luanna B. Prevost, Michelle K. Smith, and Jennifer K. Knight

Computerized lexical analysis paired with human scoring was used to explore student ideas about the effect of a stop codon mutation on replication, transcription, and translation. It was found that student ideas about one process can affect their understanding of subsequent and previous processes, leading to mixed conceptual models of the central dogma.

Development and Validation of the Conceptual Assessment of Natural Selection (CANS)

Steven T. Kalinowski, Mary J. Leonard, and Mark L. Taper

The authors present the Conceptual Assessment of Natural Selection (CANS), a new concept inventory intended to measure how well college students in introductory biology courses understand the basic process of natural selection.

Teaching about Water Relations in Plant Cells: An Uneasy Struggle

Lilianna Malińska, Eliza Rybska, Ewa Sobieszczuk-Nowicka, and Małgorzata Adamiec

University students often struggle to understand the role of water in plant cells. This study attempted to identify student difficulties (including misconceptions) concerning osmosis and plasmolysis and examined to what extent the difficulties could be ameliorated during a plant physiology course.

Toward High School Biology: Helping Middle School Students Understand Chemical Reactions and Conservation of Mass in Nonliving and Living Systems

Cari F. Herrmann-Abell, Mary Koppal, and Jo Ellen Roseman

Studies have shown that students struggle to understand basic chemical concepts and have trouble applying these concepts to biological phenomena. This article describes the development and evaluation of a unit to help middle school students connect core ideas about chemical reactions to the phenomenon of growth in animals and plants.

The Design and Transformation of Biofundamentals: A Nonsurvey Introductory Evolutionary and Molecular Biology Course

Michael W. Klymkowsky, Jeremy D. Rentsch, Emina Begovic, and Melanie M. Cooper

We describe the recursive design process used to generate a nonsurvey introductory biology course built on a framework of evolutionary (social, sexual, natural, and non-adaptive) mechanisms, physicochemical processes and constraints, and systematic behaviors that shape all biological systems. The resulting narrative (based on a free text, Biofundamentals) and associated materials are described, and the ways in which they have been revised on the basis of students' responses to drawing- and text-based formative assessments, interactive readings, and students' response to exam questions are elaborated. Strategies to encourage student persistence through assessment strategies (such as "I know it now" tests) are described.

Options for Online Undergraduate Courses in Biology at American Colleges and Universities

Alison K. Varty

This analysis of online offerings in biology indicates that offerings at 2-year public colleges are common, while 4-year public and private institutions are lagging. Biology courses commonly offered online are general education and healthcare-related courses with limited options for biology majors. Ideas to increase biology online offerings are provided.

Alternative Realities: Faculty and Student Perceptions of Instructional Practices in Laboratory Courses

Christopher W. Beck and Lawrence S. Blumer

A survey was developed on inquiry-based learning and assessment in undergraduate laboratory courses and defined five constructs: metacognition, feedback and assessment, scientific synthesis, science process skills, and instructor-directed teaching. In general, faculty and student perceptions were not related at the course and instructor levels.

Investigating the Role of an Inquiry-Based Biology Lab Course on Student Attitudes and Views toward Science

Erica Jeffery, Kathy Nomme, Thomas Deane, Carol Pollock, and Gülnur Birol

Student attitudes and views toward biology as a science were investigated in four first-year classes. Shifts were evaluated in two aspects of scientific inquiry: 1) confidence and interest and 2) understanding and acceptance. The study assesses whether varied learning experiences shift students toward more expert-like views.

Early Environmental Field Research Career Exploration: An Analysis of Impacts on Precollege Apprentices

Susan K. Flowers, Katherine M. Beyer, Maria Pérez, and Donna B. Jeffe

Longitudinal mixed-methods examination of two consecutive field-based environmental biology research apprenticeship programs for precollege youth indicates that the two-stage apprenticeship structure influenced social cognitive career variables necessary for persistence in pursuit of an environmental research career pathway.

Implementation of a Collaborative Series of Classroom-Based Undergraduate Research Experiences Spanning Chemical Biology, Biochemistry, and Neurobiology

Jennifer R. Kowalski, Geoffrey C. Hoops, and R. Jeremy Johnson

This paper describes the design, implementation, and assessment of three collaborative classroom undergraduate research experiences (CUREs) integrating faculty research interests across chemical biology, biochemistry, and neurobiology. Benefits of CURE participation included increased faculty productivity, generation of novel scientific data, and the expected CURE benefits for student learning.

Development and Evaluation of the *Tigriopus* Course-Based Undergraduate Research Experience: Impacts on Students' Content Knowledge, Attitudes, and Motivation in a Majors Introductory Biology Course

Jeffrey T. Olimpo, Ginger R. Fisher, and Sue Ellen DeChenne-Peters

This paper presents the development and evaluation of a novel course-based undergraduate research experience (CURE) for use in introductory biology contexts. Results indicate statistically significant gains in CURE students' content knowledge, attitudes, and motivation in the discipline relative to a matched comparison group.

Do We Need to Design Course-Based Undergraduate Research Experiences for Authenticity?

Susan Rowland, Rhianna Pedwell, Gwen Lawrie, Joseph Lovie-Toon, and Yu Hung

The authors conducted a metareview of published conceptions of "authentic" science laboratory education and used their students' reflections to examine the authenticity of their own laboratory curriculum design. They find that preauthentication of a learning design is not necessary to deliver an authentic experience to students.

Scientific Process Flowchart Assessment (SPFA): A Method for Evaluating Changes in Understanding and Visualization of the Scientific Process in a Multidisciplinary Student Population

Kristy J. Wilson and Bessie Rigakos

Student drawings are assessed for understanding of the scientific process. The Scientific Process Flowchart Assessment (SPFA) evaluates organization of ideas and connections between ideas (experimental design and nature of science). The method was validated for multidisciplinary use and is reliable.

The Benefits of Peer Review and a Multisemester Capstone Writing Series on Inquiry and Analysis Skills in an Undergraduate Thesis

K. F. Weaver, V. Morales, M. Nelson, P. F. Weaver, A. Toledo, and K. Godde

This study demonstrates the positive impact of peer review and a multisemester writing capstone on inquiry, science literacy, and critical thinking skills.

Perceived Challenges in Primary Literature in a Master's Class: Effects of Experience and Instruction

Richard Lie, Christopher Abdullah, Wenliang He, and Ella Tour

An analysis is presented of what master's students perceive as the most challenging aspects of primary literature before and after instruction in critical reading of scientific articles. After instruction, students increasingly focus on challenges requiring critical thinking.

Validation and Application of the Survey of Teaching Beliefs and Practices for Undergraduates (STEP-U): Identifying Factors Associated with Valuing Important Workplace Skills among Biology Students

Gili Marbach-Ad, Carly Rietschel, and Katerina V. Thompson

A novel assessment tool, the Survey of Teaching Beliefs and Practices for Undergraduates (STEP-U), is presented. STEP-U assesses the extent to which graduating biology students value skills needed for the workplace (e.g., ability to work in groups) and their experiences with teaching practices purported to promote such skills (e.g., group work).

A Case Study Documenting the Process by Which Biology Instructors Transition from Teacher-Centered to Learner-Centered Teaching

Gili Marbach-Ad and Carly Hunt Rietschel

A case study approach was used to obtain an in-depth understanding of the change process of two university instructors who were involved with redesigning a biology course to implement learner-centered teaching. Implications for instructors wishing to transform their teaching and for administrators who wish to support them are provided.

Examining the Role of Leadership in an Undergraduate Biology Institutional Reform Initiative

Rebecca L. Matz and Sarah E. Jardeleza

The authors studied a reform process in undergraduate biology at a research-intensive university to explore what leadership issues arose in implementation of the initiative when characterized with a descriptive case study method. They found that easing the burden of an undergraduate education reform initiative on faculty through articulating clear outcomes, developing shared vision across stakeholders on how to achieve those outcomes, providing appropriate reward systems, and ensuring faculty have ample opportunity to influence the initiative all appear to increase the success of reform. An extended model of change is presented that moves from change in STEM instructional strategies to STEM organizational change strategies.

The PULSE Vision & Change Rubrics, Version 1.0: A Valid and Equitable Tool to Measure Transformation of Life Sciences Departments at All Institution Types

Loretta Brancaccio-Taras, Pamela Pape-Lindstrom, Marcy Peteroy-Kelly, Karen Aguirre, Judy Awong-Taylor, Teri Balseg, Michael J. Cahill, Regina F. Frey, Thomas Jack, Michael Kelrick, Kate Marley, Kathryn G. Miller, Marcy Osgood, Sandra Romano, J. Akif Uzman, and Jiuqing Zhao

This paper describes the development and validation of the PULSE Vision & Change Rubrics, version 1.0, a reliable tool for measuring departmental change. It was found that liberal arts institutions are farther along in implementing the recommendations of *Vision and Change* and that institutions overall earned the highest scores on the Curriculum rubric and the lowest scores on the Assessment rubric.

Introducing the Postsecondary Instructional Practices Survey (PIPS): A Concise, Interdisciplinary, and Easy-to-Score Survey

Emily M. Walter, Charles R. Henderson, Andrea L. Beach, and Cody T. Williams

The Postsecondary Instructional Practices Survey (PIPS) is a valid and reliable measure of self-reported instructional practices of postsecondary instructors, including individuals outside science, technology, engineering, and mathematics. This paper describes the development and validation processes, scoring conventions and results outputs, and applications of the PIPS.

Making the Grade: Using Instructional Feedback and Evaluation to Inspire Evidence-Based Teaching

Peggy Brickman, Cara Gormally, and Amedee Marchand Martella

Survey results from a random sample of U.S. college biology faculty identify an overwhelming dissatisfaction with end-of-semester student evaluations. Instead, faculty desire greater guidance from peer observations as well as student assessment data to help inform curricular and pedagogical decision making.

On the Cover

Gloeotrichia, a colonial cyanobacterium. Filaments arrange themselves in starlike colonies. Large numbers of colonies can collect in freshwater lakes, forming blooms. Sixth Prize, 2005 Olympus BioScapes Competition. Spike Walker. This image is licensed under a Creative Commons Attribution, Non-Commercial, No Derivatives License and can be found on the Cell Image Library at <http://www.cellimagelibrary.org/images/42510>.