REVIEW

Evolution Challenges: Integrating Research and Practice in Teaching and Learning about Evolution

edited by Karl S Rosengren, Sarah K Brem, E Margaret Evans, and Gale M Sinatra
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reviewed by Tania Lombrozo

Evolution Challenges brings together 19 chapters by 36 contributors to tackle the thorny challenges associated with teaching and learning about evolution. The contributors are predominantly drawn from university faculty and researchers in departments of psychology, biology, or education with methodological expertise ranging from laboratory studies to the development of pedagogical materials for classrooms, museums, and the Internet.

The first half of the volume focuses on the cognitive and perceptual constraints that influence people's understanding and acceptance of evolution. As emphasized by E Margaret Evans, Karl S Rosengren, Jonathan D Lane, and Kristin LS Price, such constraints can both help and hinder learning. For example, by the time students encounter the idea of evolution, they already have some ideas about biological categories: children tend to think of species as fixed and discrete categories in the world, where all members of a species share some common "essence." This idea, known as "psychological essentialism," is discussed in detail by Susan A Gelman and Marjorie Rhodes in the book's opening chapter. One problem with psychological essentialism is that it makes it hard to understand speciation: how one fixed and discrete category could evolve into another.

Psychological essentialism conspires with other aspects of "folk" biological categorization, highlighted by John D Coley and Tara M Muratore, to make natural selection especially challenging to understand. When we think about biological species, for instance, we typically represent the mean or average of the category rather than the variation within it. To make this concrete, think about wombats. Chances are you imagined one or more "typical" wombats without thinking much about natural variation in wombat color, strength, or personality. But without variation, there's nothing to generate heritable differences in reproductive success, and therefore nothing for natural selection to differentially "select."

Unfortunately, problematic psychological biases don't end there. Deborah Kelemen documents children's general preference for purpose or "teleology", and Camillia Matuk and David Uttal suggest a human tendency to impose a compelling narrative structure on evolution, a "March toward Man". These biases contribute to misconstruing evolution as a goal-directed process that operates over individual members of a species. Michelene TH Chi, Agnieszka Kosminska Kristensen, and Rod D Roscoe capture many of these misconceptions in suggesting that people fail to recognize natural selection as an emergent process that operates at the level of a population.

What's to be done? The contributions in the second half of the book take up this question, proposing and evaluating strategies for teaching evolution to different kinds of learners (children, adults, and teachers) in a variety of contexts (classrooms, museums, and online). For example, a chapter by Paul M Beardsley, Mark V Bloom, and Sarah K Wise synthesizes the upshot of two dozen or so published papers reporting evidence for educational strategies that improve students' understanding of evolution. While their recommendations vary for different age groups, it's clear that lectures are a very ineffective way to improve understanding, with more evidence of success for inquiry-based activities, curricula that acknowledge students' pre-existing misconceptions, and collaborative learning. Judy Diamond, Patrick Kociolek, Evans, and Amy N Spiegel provide nice discussions of the role of museums in both perpetuating and overcoming misconceptions concerning evolution, as well as the ways in which psychology can inform the design of exhibits, and in turn provide a venue for novel research. Anna Thanukos and Judy Scotchmoor provide an informative summary of successful efforts to provide accessible lessons about evolution and the nature of science for teachers and the general public through websites like Understanding Evolution and Understanding Science.

Several themes were particularly striking as I read through this diverse collection. First, people's understanding of evolution is heterogeneous, not only in the sense that it varies across people, but also in that some evolutionary ideas are easier for people to grasp than others. Microevolution is less challenging than macroevolution, for instance, and differential survival less problematic than differential reproduction. Accordingly, different evolutionary concepts present different challenges for learners and educators, and sometimes benefit from different pedagogical approaches.

Second, people's understanding of evolution is embedded within larger frameworks concerning their understanding of science and religion. In a subsection of the book sandwiched between an early focus on psychological biases and the final chapters on educational implementation, three authors tackle "epistemological issues" in learning, with Clark A Chinn and Luke A Buckland advocating approaches to instruction that engage learners in generating and evaluating models, Ryan D Tweney identifying the epistemology of "folk religion" as an important barrier to understanding evolution, and Michael Andrew Ranney considering larger sociological, religious, and nationalistic influences on people's acceptance of both evolution and climate change. Craig E Nelson also advocates teaching evolution within a broader dialogue about science and religion, and many contributors advocate teaching the nature of science alongside evolutionary content.

Third, big misconceptions don't always require big interventions. Evolution education faces a number of challenges, and most attempts to teach evolution have a modest track record, generating minor improvements for a subset of students after considerable investment. But the book presents some impressive examples of relatively minor changes that can have big effects. For example, Kefyn M Catley, Laura R Novick, and Daniel J Funk discuss the importance of "tree thinking" and document perceptual biases that lead students to misunderstand the evolutionary relationships depicted by cladograms when they are presented in a "ladder" format, where taxa branch off lines forming Vs. The simple shift to a "tree format," where relationships between taxa correspond to more natural perceptual units (more like square brackets), leads to marked improvement in student understanding. Similarly, Matuk and Uttal report that something as simple as having cladograms appear to students in an

animation from top to bottom disrupts the misleading sense that the diagrams depict a temporal sequence from left to right or bottom to top.

The volume also includes examples of more extensive educational interventions that can yield positive results. For example, Andrew Shtulman and Prassede Calebi describe a curriculum in which they guide students through Ernst Mayr's (1982) "derivation" of natural selection from superfecundity, resource limitation, trait variation, and trait heritability. Sherry A Southerland and Louis S Nadelson describe a course for preservice teachers in which they encouraged students to consider the political, religious, and emotional barriers to evolutionary understanding. And as a final example, Diamond, Evans, and Spiegel report that a visit of about 20 minutes to the Explore Evolution exhibit was sufficient to improve children's and adults' understanding of key evolutionary concepts such as common descent and natural selection. While researchers and museum staff made an enormous investment in designing the exhibit, the short time required to peruse the exhibit is a relatively minor investment on the part of museum visitors, making it impressive that learning gains were observed at all.

A final theme that runs throughout the volume concerns the goals of science education in general, and of evolution education in particular. Several contributors raise questions about whether the correct goal for educators is to have students understand evolution or to accept it as well. To quote a final commentary by Sarah K Brem and Gale M Sinatra: "Philosophically, we may find that we want understanding, and feel troubled pushing for acceptance; emotionally, understanding without acceptance seems fraught with peril and leaves us wondering if we have fully accomplished our jobs as educators" (p 438). These issues engage with broader questions about the role of education for individuals and for a democratic society.

Overall, this is a broad-ranging volume that straddles basic research on evolutionary understanding and educational practice. As a result, it's likely to have something new for both teachers and researchers, and may be of interest to general readers hoping to learn more about the psychological underpinnings of people's understanding (or misunderstanding) and acceptance (or rejection) or evolution. The chapters are well written and fairly accessible, but this over-450-page tome is not a light read for the uninitiated.

Eugenie C Scott concludes the volume's foreword with a quote from Darwin on natural selection—"There is grandeur in this view of life"—and suggests that the book's content will "help us to convey that grandeur more emphatically, more empathetically, and more effectively than ever before" (p xii). This is an important book on an important set of topics, sure to elevate discussion (if not alleviate distress) when it comes to the challenges of teaching and learning about evolution.

REFERENCES

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