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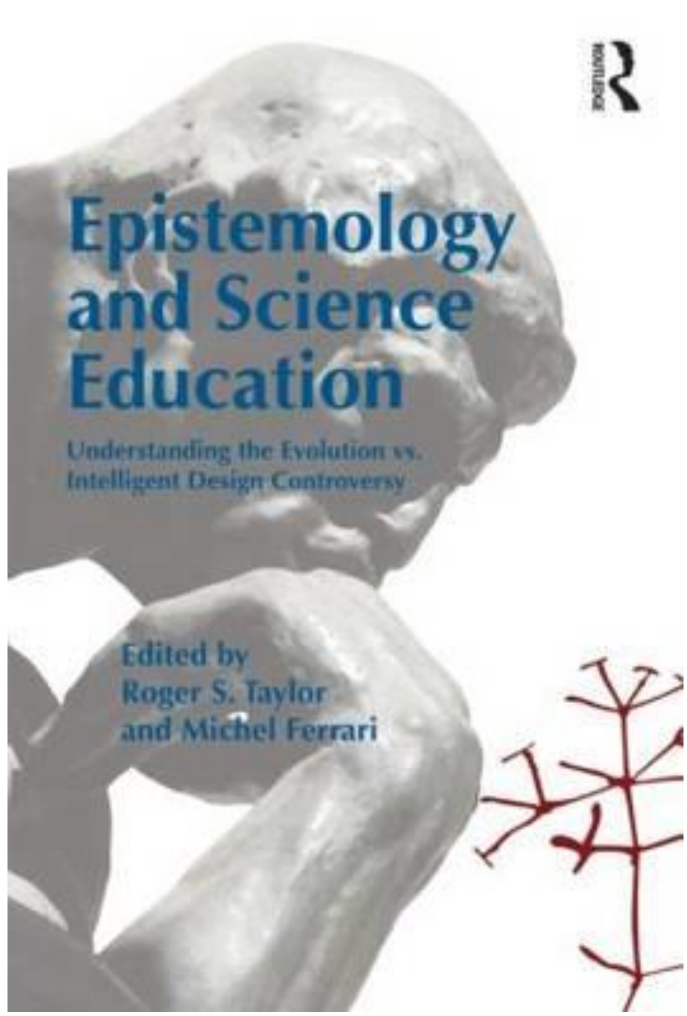

For decades the creationist movement has threatened the teaching of evolution in the United States, even in public schools. Similar worrisome trends have started in other Western countries. Beyond the major importance of reacting to attempts to undermine the proper teaching of evolutionary biology, the intelligent design issue should remind educators of the need to teach students about the nature of science and the practice of scientific knowledge formation—even in countries without objections to evolution education. While many recent books and edited volumes have addressed why intelligent design is flawed or what makes it bad science, concrete suggestions for how to improve the teaching of evolution at the secondary level have been less common. *Epistemology and Science Education: Understanding the Evolution vs. Intelligent Design Controversy*, edited by Roger Taylor and Michel Ferrari, makes a timely and welcome contribution to this aim by gathering essays that are theoretically informed by educational psychology, among other fields, and in most cases present recent cognitive psychology studies or some classroom projects. An in my view particularly interesting feature is that several essays—based on different education psychological reasons—converge on the recommendation that beyond the traditional classroom focus on different aspects of microevolution, it is vital to teach *macroevolutionary* change and human evolution.

Epistemology is the focus of the six essays in the first part, moving from the nature of science to student cognition. Paul Thagard reviews recent philosophical views about the nature of science, scientific theories, and explanations. Most philosophers of science maintain that there is no sharp and domain-independent demarcation of science from pseudo-science, but Thagard's criteria still illustrate how intelligent design falls short of actual evolutionary biology.

While philosophers have moved away from the view that science exclusively consists in the inferring of predictions and testing of hypotheses to more sophisticated views, Richard Duschl and Richard Grandy explain why the same ought to happen in secondary school classrooms. Their dialogic practice view of scientific method offers students a much better appreciation of why intelligent design does not participate in crucial epistemic and social practices characteristic of science; and they recommend portraying science not as tentative claims but as *responsive* to anomalous data.

In a similar vein, Clark Chinn and Luke Buckland drive home that the issue is not whether a theory is scientific, but whether epistemic practices are so. Based on a variety of considerations, they compare the practices of evolutionary biologists, young earth creationists, intelligent design creationists, and 19th century scientist-creationists—the latter are included as based on their practice they turn out to be more scientific than even contemporary intelligent design proponents are.

Addressing epistemology in the context of student cognition, Ala Samarapungavan discusses empirical work on Dutch children's views on species change and the formation of new species, illustrating the presence of different explanatory frameworks in different children before they enter formal instruction. Her recommendation for evolution education is to teach the full range and interrelatedness of different kinds of evidence for evolution. As children can more easily imagine microevolutionary change than substantial structural evolution across species, more examples of macroevolutionary change ought to be presented by teachers.

Barbara Hofer, Chak Fu Lam, and Alex DeLisi report on ongoing studies about American college students' views on knowing and knowledge, and how this relates to their degree of acceptance of evolution. They point to widespread misunderstandings of the scientific meaning of 'theory' (even among college students), and wonder whether students growing up in the American system confuse tolerance of different views with relativism. A suggestion is that educators create more cognitive conflict to effect conceptual change among their students.

Margaret Evans, Cristine Legare, and Karl Rosengren discuss multiple epistemologies, where both natural and supernatural factors are being appealed to, for instance, each in different contexts in a domain, at different steps of a causal sequences, or in a fused fashion. The operation of multiple epistemologies is shown by two kinds of studies: South African's views on the origin of AIDS and Western children's assumptions about death. Their findings suggest that the teaching of evolution should not focus on microevolutionary change and non-human evolution only, as teaching a scientific epistemology in those domains need not prevent student from using a different, non-scientific epistemology for human macroevolution. Even though it makes the material more attractive, the anthropomorphizing of nature in classrooms or exhibitions can have deleterious effects on student's epistemological development.

In the book's second part on creation vs. evolution, Michael Ranney and Anastasia Thanukos study how US college students accept evolutionary explanations on different issues pertaining to adaptation or common ancestry in different organism domains (plants, animals, humans). Needless to say, in the overall population there is more reluctance to accept human than animal or plant evolution, but they show that this effect is stronger in and largely attributable to the group of students who are generally less accepting of evolution. Interestingly, those positive and neutral towards evolution are more accepting of a particular human evolution claim when it involves cross-species similarities (common ancestry) than when it involves adaptation hypotheses (as here non-evolutionary explanations in terms of learning are possible). The essay discusses accounts of why evolution has become so contested in the US, pointing to a theistically based national destiny self-image as a neglected factor, which would also explain the common rejection of the idea of anthropogenic climate change in the US.

Gale Sinatra and Louis Nadelson assess how religion, intelligent design, and evolutionary theory differ epistemologically, urging the pedagogical need to clearly distinguish religion and science as different epistemologies that explain different aspects of the human condition. This would provide those learners tempted to view science and religion as in conflict a conceptual place to stand. Instruction about evolution should start out with a discussion about the nature of science, including its epistemological commitments and limitations, for instance, by first using plate tectonics as an illustration before moving on the controversial issue of evolution.

The essays in the last part very directly address the teaching of science. Ryan Tweney discusses why it is much harder to entertain religious than scientific ideas. Using an experiment conducted by Faraday as an example, he recommends teaching that scientific reasoning essentially involves the researcher's skepticism. However, in my opinion it is more characteristic of science (and more fruitful for science education) that scientific methods contribute to revising and improving current views, which is not just due to the attitude of individual researchers—on which Tweney's account focuses—but the collaborative nature and institutional setting of science. It is important to present experiments to students that effectively show that there are invisible entities as in his Faraday example, but in contemporary science (climate change is just one example) the justification of some theories occurs in a collaborative and expert-based manner that cannot be 'shown' to students—this is something about justification in science that has to be conveyed to students as well.

A very intriguing essay by Uri Wilensky and Michael Novak reports on the results of classroom studies using computer-based modeling. The pedagogical target is emergent processes occurring in evolution, which are usually very hard to understand for students, as they conflate properties of individuals and of populations and tend to explain pattern as being orchestrated by a leader or central control, rather than emerging from local interactions. (I note the irony that while US conservative dogma asserts that an economy is not to be organized in a centralized fashion and that a socially optimal market can emerge from individual businesses' actions, often the same persons claim it to be inconceivable for complex biological traits to evolve in an unguided fashion.) In Wilensky and Novak's computer models students can change parameters and study the system's development in a visual fashion. Different models are used to teach the emergent phenomena of genetic drift, natural selection, competition among different species, and coevolution, with the study showing the pedagogical usefulness if this tool.

Michel Ferrari, Peter Lee and Roger Taylor discuss genetic algorithms and call for engaging students more by integrating the learning of natural science with other concerns including personal meaning ("contemplative wisdom"). Though genetic algorithms and teaching for wisdom are important, the essay does not connect these different topics, leaving each being treated with insufficient detail.

In addition to the various empirical results presented and individual pedagogical insights made in this worthwhile collection of essays, one important lesson is that science instructors should devote more time to teaching about and making students reflect on the *nature* of science and the epistemological *practices* of scientists—rather than merely teaching particular scientific facts and theories. Students are likely to get a better appreciation of the evidence for evolution and how evolutionary biology differs from intelligent design if they are made aware of the nature of scientific explanation and the practice of improving scientific beliefs.

An issue that is not discussed by the authors (though Ferrari et al.'s contemplative wisdom hints at it) is the teaching of how *ethical principles* are justified and criticized. While many instructors (especially in the US) shy away from addressing ethics and while it is not a topic for science classrooms, this issue should be discussed and studied by education scholars as in many students' minds naturalistic science is tied to a moral relativist or amoral worldview. Just like there are better and worse ways of forming beliefs about the natural world, there are better and worse ways of justifying ethical and social values—how to do the latter could be conveyed to students. Amorality vs. religiously based moral dogma is a false dichotomy; and it is possible to use a scientific epistemology *and* ethical justification. After all, scientists publicly support theories about anthropogenic climate change not only because of its empirical evidence, but because they recognize its environmental and societal importance.