

The “Freezing” of Science: Consequences of the Dogmatic Teaching of Ecology

RAFAEL GONZÁLEZ DEL SOLAR AND LUIS MARONE

One of the most important achievements of science is, perhaps, its contribution to the elimination of the idea of an intangible and eternal truth.

François Jacob,
Le Jeu des Possibles

In his classic work “The Essential Tension: Tradition and Innovation in Scientific Research,” the historian and philosopher of science Thomas S. Kuhn (1991) asserts that natural sciences are taught almost exclusively from textbooks written especially for students at both graduate and postgraduate levels, and, as often as not, these textbooks do not describe the sorts of problems the future professional will very likely have to deal with, nor the variety of techniques available to treat them. Instead, he says, textbooks usually offer a concrete solution—the “paradigmatic” one—as a model for how to solve similar problems. Continuing, he points out that students are not encouraged to read the classical works of their field, and the learning process is a sort of dogmatic initiation in a tradition that students are not prepared to evaluate for themselves. In sum, textbooks and teachers frequently offer versions of science that—as philosophers David Hume and Karl R. Popper have shown—are unsustainable from the logical point of view (Popper 1977).

According to Kuhn (1991), though, the described teaching strategy plays a central role in the development of scientific knowledge, promoting the consensus, knowledge, and thoroughgoing commitment that allow scientists to bet their intellectual lives in the attempt to articulate a particular paradigm—even against rebellious data—and to add, in the long run, to the development of science. Like Kuhn, we understand that thorough knowledge of one’s field of research, and consensus, are necessary to contribute to science development. Unlike Kuhn, we believe that dogmatic teaching of science is not advisable in any sense or stage of the educational process, for scientific practice depends on rational inquiry, and rational inquiry in turn depends on critical thinking.

In this article, we analyze some epistemological attributes of ecological hypotheses and theories and try to connect them with the need for teaching strategies that take into account the strong provisional character of ecological knowledge. We submit that the dynamism of ecology’s hypotheses and theories suggests that dogmatic teaching in this field is very likely to have negative effects on future ecology and ecologists. We accordingly try to show that critical thinking is an essential tool in both learning and practicing ecological science.

The provisional character of scientific theories

One essential feature of empirical science is that the truth or falsity of its theories cannot be definitively established. Definitive verification is impossible, no matter the number of corroborative cases found. The same holds for refutation (Popper 1977, Lakatos 1997). This epistemological standpoint—fallibilism—maintains that, because certainty is beyond possibility, scientific knowledge must be viewed as provisional. This is so even for factual data, because data are always interpreted in light of some previously accepted theoretical framework (Bunge 1998). Should this theoretical framework change, the interpretation of data would change. It is worth noting that this perspective does not amount to radical relativism. Radical relativism denies the possibility of objective truth, and in so doing it incurs self-refutation (Siegel 1987).

Rafael González del Solar (e-mail: aragorn@lanet.com.ar) and Luis Marone are scientist researchers with ECODES (Desert Community Ecology Research Team), Unidad de Fisiología y Ecología Vegetal, National Institute for Research of the Arid Zones, Casilla de Correo 507, Mendoza 5500, Argentina. González del Solar is a biologist and professor of epistemology interested in the philosophy of ecological science. Marone is a biologist interested in community ecology and epistemology. © American Institute of Biological Sciences.

Fallibilism, however, can be combined with different varieties of realism to maintain that it is possible to utter true statements even though we cannot be absolutely certain of their truth—that is, they remain conjectural to a certain extent.

As an empirical science, ecology must deal with the provisional character of its hypotheses at educational and professional levels, and one powerful tool for doing so is critical thinking: namely, a set of analytical tools for evaluating the logical consistency of arguments and their correspondence with factual evidence. Certainty will remain impossible, of course, but educated evaluation of alternatives—one primary goal of education and of science—will not.

Regrettably, this outlook does not seem to be the one commonly held in university circles, where ecological theories are frequently taught as if they were facts and not fallible human knowledge. Thus, a sort of freezing befalls scientific knowledge, which is regarded then almost as a thing instead of a conceptual system (i.e., a set of interrelated ideas).

In this context, the role of students is to passively absorb such definitive knowledge. Therefore, a most characteristic activity of empirical scientists, namely, a particular kind of rational critique—through which it is possible to decide between two or more conjectures competing as explanations of a portion of the world—is not practiced during a substantial part of the learning process.

The dynamism of ecological theories

Students of sciences such as physics might (only might) not suffer so strongly from the effects of knowledge freezing at the university, inasmuch as most physical theories have high generality and are replaced less frequently than those in other scientific fields. In contrast, ecological theories have a low level of generality and little formalization and systematization (i.e., deductive connections), conditions that make it difficult to integrate and establish ecological knowledge (Pickett et al. 1994, Mahner and Bunge 1997). These difficulties are attributable, on the one hand, to the existence of cases in which different conjectures (hypotheses or theories) formulated to explain a particular phenomenon may coexist for an indefinite time, because their “domain of generality” is limited with regard to temporal, spatial, or organismal scales (Dunham and Beaupre 1998). Although they compete in some way, these conjectures are not mutually exclusive and thus are not true rivals, because the statements expressing them are not universal but existential—they refer to only *some* objects or circumstances—or probabilistic (Pickett et al. 1994).

On the other hand, ecology’s more general statements have little stability. That is to say, they are replaced at a relatively quick pace (Pickett et al. 1994, Mahner and Bunge 1997). Sometimes theory replacement occurs as a result of the critical examination of the validity and subsequent rejection of certain assumptions. For example, the existence of some kind of ecological equilibrium was an assumption widely accepted in ecology’s theoretical development in the 1950s and 1960s (MacArthur 1972). When this assumption was revised in light of empirical evidence, equilibrium was not considered

an axiom anymore, but just a hypothesis subject to testing. From then on, theory developed both under the assumption of the existence of an ecological balance and under the assumption of its nonexistence (Wiens 1989). The utilization of models without the assumption of ecological equilibrium produced deep changes in ecological research, which, despite their importance, passed into the educational field and into society at only a very slow pace (Marone 1988).

At other times, theory replacement may derive from the simultaneous revision of the assumptions and the empirical evidence supporting a theoretical construction. This case can be illustrated by the changing interpretations of the relationship between diversity and stability in food webs, stemming from the ideas of Robert MacArthur, one of the fathers of 20th-century ecology. MacArthur’s (1955) original and intuitive proposal was that more stable communities would have longer and more intricate food webs. Later, theoretical studies strongly suggested that complexity usually destabilizes food webs (May 1973, Pimm et al. 1991), and this assertion received some empirical support (Lawler and Morin 1993). Recently, however, food web theory suffered another change: McCann and colleagues (1998) showed that MacArthur’s idea does indeed explain the behavior of certain communities, provided that multiple weak interactions are assumed to prevail along food chains. McCann and colleagues (1998) formulated several mechanistic models wherein weak interactions promoted community persistence and stability, and, moreover, they used realistic estimators of interaction strengths, defined as the likelihood of consumption of one species by another.

Finally, the substitution of hypotheses and theories may also come from the use of new research protocols or from the revision of some of the assumptions of the field or laboratory techniques. For example, the result of enclosure experiments with rodents of the genus *Dipodomys* (kangaroo rats) in the Chihuahuan desert drove specialists to make the generalization, prevalent for the last two decades, that the disappearance of kangaroo rats induces (a) an increase in the density of the smaller rodents via relaxation of competition and (b) an increase in the number of plants with heavy seeds via the absence of their main seed consumer (Brown 1998). The key role of *Dipodomys* as efficient competitors and selective granivores was inferred by using “mechanism-free experiments” (Dunham and Beaupre 1998). Therefore, different mechanisms may be invoked to explain both the increase of putative competitive rodents (e.g., the lack of large predators like some viperid snakes within the enclosures; Dunham and Beaupre 1998) and that of certain plants (e.g., a combination of granivory and folivory by *Dipodomys*; Kerley et al. 1997). Although the usefulness of manipulative mechanism-free experiments is not under debate here, their combination with mechanism-explicit experiments would probably challenge the general validity of some long-standing hypotheses of North America’s desert ecology.

Without ecological knowledge being certain, ecologists must constantly revise their understanding of natural systems. Frequently, new evidence or the analysis of assumptions gives

rise to the replacement of hypotheses and theories. This is an important point, because scientific progress occurs when—although not always when—a theory or series of theories is replaced by another one that is preferred on the basis of logical, empirical, and pragmatic criteria (Popper 1977, Putnam 1991, Lakatos 1997, Bunge 1998). Thus, it seems obvious that any attempt to solidify the dynamic state of modern ecological studies would have negative consequences for the understanding of ecological communities, current food web theory, or the role of granivory in deserts.

Consequences of the dogmatic teaching of ecology

As can be deduced from the foregoing paragraphs, artificially depriving future professionals of an appreciation of ecology's provisionalism may have devastating consequences. One important consequence of this solidification of knowledge would be that students would be encouraged to believe that ecology is something it surely is not: a set of immobile truths. Thus, students are invited to believe in a notion of knowledge much less similar to modern empirical science than to wisdom, as the ancients used to see it, namely, something that cannot—and must not—be argued against. The perils implied in this view are many.

Dogmatic teaching of ecology overlooks the importance of rational inquiry. The whole scientific enterprise depends on the ability to inquire about how the world is, and rational inquiry is not possible if people are incapable of doubting the already available accounts of the world. Scientists must see the possibility of suspecting their (and others') prejudices in order to inquire. Plausibly, a scientific problem should be deemed understood only when a critique of its formulation and available solutions is possible.

Dogmatic notions of science have other major drawbacks. Dogmatism puts scientific research in the same box as religion, thus inflaming relativistic attacks on science. This topic has been treated in numerous articles dealing with the decision of the Kansas Board of Education to discourage the teaching of evolution (see, for example, Johnson G 1999, Johnson P 1999). The board saw no reason to ask students to take into account evolutionary theory as a part of their education, because evolution, they argued, is not a fact but *just* a theory. The problem is clear: The board forgot that the alternative to evolution—creationism—is not even a theory, and that is exactly what makes the difference. The point is not to ask someone to believe something on the say-so of a particular authority but to give the students the opportunity to know different standpoints, to think, evaluate, and decide for themselves. Unless one adheres to radical relativism, science is indeed an interesting and powerful standpoint in the specific areas in its domain (Tauber 1999), and the evolution of life is certainly a part of the domain of biological science. To put it in another way, it is not truth that separates science from religion, but rational criticism as opposed to dogmatism. Science should leave dogmatism to religion if it is to continue to be a rational enterprise, for rational knowledge of reality is

admittedly fallible. We agree with Miller (1999) when he states that giving science its conjectural character back might reduce the number of disappointed people who increase the legions of irrationalism (although we think that the absolute skepticism he advocates is not an answer, because beliefs are simply inevitable; see Bunge 2001, chap. 7).

Another undesirable consequence of dogmatic teaching of ecology is that students may believe that they understand how science works, whereas they are being exposed only to some of its products. In addition, the pertinence and usefulness of these products will presumably decrease over time as theories are replaced, rendering obsolete the static ecological knowledge learned in college. Students will face the consequences of the inadequacy of their instruction when they become professionals and realize that they were not given the relevant tools for solving real problems.

As we implied at the beginning of this paper, the need for recognizing ecology's strong dynamic side corresponds with the need for preparing students for rational inquiry and critique. Thus, scientific instruction is not only content transmission but also the attempt to guide free people in investigating a complex, not fully understood, and even somewhat mysterious world.

Strategies for improving the teaching of ecology

University teaching of ecology should be closer to ecological research to prepare future ecologists for research or teaching. Making the learning process parallel the process of scientific research would improve students' understanding of the rationale of ecological research. Different teaching models may contribute to this goal, and those protocols inspired by the scientific process of inquiry itself are surely most appropriate (Feinsinger et al. 1997, Switzer and Shriner 2000). Such hands-on approaches applied to science learning are much better than lectures or textbook reading alone, because they provide a realistic environment for the practice of some of the skills actually involved in ecological research. But one must bear in mind that, essential as they are, the laboratory and the field cannot teach ecology by themselves. Some guidance is needed. Theoretical interpretation is always present to some extent in scientific research (Bunge 1998). Therefore, an extreme empiricist approach naively pretending to work only with facts would be just a blind approach, making it impossible for researchers to recognize their own prejudices (hidden accepted theories or hypotheses), and people cannot subject to criticism that which is hidden from them. Thought should be "moving" before hands start to move. Enter the role of lectures: These may sometimes contribute to a particular process of inquiry, guiding the students in posing ecological problems and making them aware of the theoretical framework any possible question assumes. For example, some lectures encouraging epistemological or methodological discussion of the importance of assumptions in scientific research would encourage students to be more suspicious of—and therefore less vulnerable to—fashionable theories or practices.

Textbooks also have a role in the learning process, but that role is surely not the transmission of dogma. Textbooks could be used to show an integrated view of ecological science, provided that they offer a conjectural approach to knowledge and pose interesting not-yet-solved ecological problems. In any event, students should also be encouraged to read the classics in the field, as well as some up-to-date publications on the relevant issues of today's ecological discussion. By reading the classics, students will have the opportunity to become acquainted with some of the original ideas—including theoretical and practical problems—that gave rise to ecological science. Students would also be able to view and analyze the tools (i.e., protocols and techniques) that were available at the beginning of the study of natural systems. By comparing classical and up-to-date readings, students will be exposed to the historical dimension of ecology. By analyzing the arguments and experiences that contributed to theory replacement, the relevant elements of the process (especially the rational ones) will be more evident and will stimulate critical judgment.

It is also important that students be exposed to real, specific ecological problems that challenge their intellectual abilities—that is, problems that cannot be solved using a preestablished formula. Thus, students will be able to appreciate the role of imagination and creativity in scientific inquiry, and the inevitable uncertainty involved in scientific activity and in its results. The resolution of a problem—the result—should not be so important at this stage as the method used in the attempt to achieve it—the process.

The learning process in ecological science (and in other disciplines as well) would benefit if the provisional character of scientific theories were preserved in university teaching. The fallibilistic notion of science adds to a more adequate perception of the activities involved in an ecologist's professional life, including the uncertainty of the task. Science is not a cookbook but an intellectual adventure undertaken by free-inquiring human beings. As scientists, we throw our theoretical nets into the ocean of the unknown in hope of a good harvest of understanding. This sometimes happens as we wish, usually after great effort. Sometimes, though, we do not harvest at all. Being aware of these characteristics of scientific activity will surely help students become better professional ecologists. Through the promotion of critical attitude, they will be more prepared to move nimbly among old and new alternative explanations of reality. Future researchers will most likely avoid being mere dogmatic repeaters—priests of a new secular religion—if they learn to use their imagination and develop critical thinking.

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