

# Book Review

## *Understanding Scientific Reasoning* by Ronald N. Giere

DAN BOONE *Indiana University of Pennsylvania*

Giere, Ronald N. (1991). *Understanding Scientific Reasoning* (3rd ed.). Fort Worth, TX: Holt, Rinehart and Winston. Pp. xiv, 1-322. ISBN 0-03-026419-7. Paper. US \$22.00.

Few textbooks in philosophy have ever undergone revisions as sweeping and salutary as Ronald Giere's *Understanding Scientific Reasoning*. The Third Edition is such a complete overhaul, it deserves a fresh appraisal by anyone familiar with the two earlier editions. My own inclination is to receive the changes with enthusiasm.

Giere states his avowed purpose and intended audience in the opening of the Preface:

*Understanding Scientific Reasoning* was originally motivated by a desire to make some aspects of the philosophy of science relevant to the needs of all students. It now also serves the widely recognized goals of improving critical thinking skills and contributing to general scientific literacy. It is explicitly directed toward first- and second-year college students who have not yet chosen a major area of study. Its specific purpose is to help these beginning students acquire cognitive skills in *understanding* and *evaluating* scientific material as found in college textbooks and in a wide variety of both popular and professional printed sources. (3rd ed., p. iii)

Several welcome features which help the book achieve these stated goals have *not* changed in the various editions:

First, the book is written in student-friendly language. Jargon and excessive

scientific terminology are totally absent. Giere lucidly clarifies his ideas with abundant examples, explanatory diagrams, helpful comparisons with other concepts used earlier, rephrasings, and frequent summaries. He not only uses simple language, but also provides explanations which are a model of what good textbook writing should be. Therefore, I wish to take friendly exception to his claim that the book is for first and second-year college students. It would not be surprising to find successful uses of the book at the high school level, and not necessarily just with abler students. Moreover, I have found that college seniors, even science majors, greatly profit from the book. We shouldn't assume that science majors are given much opportunity (let alone are encouraged) to reflect critically upon the processes of reasoning and justification even within their own disciplines. They may be absorbing how to *do* discipline-specific reasoning, but few make it to the meta-cognitive level of *appreciating* what they're doing and why they're doing it. (It will be discussed later in the review why this should not be seen as question-begging in the face of McPeck-type criticisms.)

Second, Giere has filled the book with *real* examples. This is even more true of the Third Edition. The student encounters not artificial, concocted exercises and examples, but authentic cases of scientific research. Many of these examples are edited and presented in non-technical language so that they are easily understood by

the non-specialist, but there are numerous excerpts straight from the literature. The examples are diversely chosen to range over the natural, social, medical, and even (in one chapter) the "marginal" or pseudo-sciences. Thus, the student is given much practice on genuine cases while working through Giere's program for understanding and critically evaluating scientific reasoning. This argues well for the transferability of these critical reasoning skills not only to other college courses but to life beyond college. (Giere notes another goal of the book in Chapter One: educating citizens able to reason critically about science and technology in our increasingly science-dominated society.) The project-exercises at the ends of some of the chapters also promote transfer. They make the student seek out genuine examples of scientific reports and carry out the chapter's program on them. All three editions of the book have this valuable emphasis on actual scientific practice. The Third Edition, because of the extensive programmatic changes, promises to strengthen that emphasis considerably. (Indeed, it isn't quite accurate to describe the first two editions as having a "program." Something like a program is present implicitly, but it has now been modified and made explicit in the Third Edition in what is even titled "The Program.")

#### *The Old Version:*

In Part One of the first two editions the student is introduced to basic concepts in logic and epistemology. This includes elementary treatments of some formal logic concepts; brief discussions of belief, knowledge, and certainty; an introduction to the deductive/inductive distinction; and a meat-and-potatoes presentation of valid and invalid conditional argument forms: *modus ponens*, *modus tollens*, affirming the consequent, and denying the antecedent. All of this is absent from the Third Edition. Part Two in the old editions introduces an

account of scientific theories and hypotheses, leading into the core chapter of the book, Chapter 6, in which Giere presents his account of the justification of scientific theories. This account includes an extensive discussion of three requirements for a "good test" of a theoretical hypothesis:

1. The prediction is logically DEDUCIBLE from the hypothesis together with the initial conditions.
2. Relative to everything else known at the time (excluding the hypothesis being tested), it must be IMPROBABLE that the prediction will turn out to be true.
3. It must be possible, at the appropriate time, to VERIFY whether the prediction is in fact true or not. (2nd ed., p. 105)

Giere develops the first two of these requirements into "Condition 1" (the DEDUCIBILITY CONDITION) and "Condition 2" (the IMPROBABILITY CONDITION) which are symbolic versions of the two requirements. Next Giere presents in excruciating symbolic detail the steps in: (1) arguments which *refute* hypotheses, and (2) arguments which *justify* hypotheses. These arguments incorporate, respectively, Condition 1 and Condition 2 as important steps in the two sequences. For example, here is the "Justifying Argument":

First Premise: If (Not H and IC and B),  
then very probably Not P.

Second Premise: P.

Preliminary Conclusion: Not (Not H and  
IC and B)

Preliminary Conclusion: H or Not IC or  
Not B

Additional Premise: IC and B.

Conclusion: H. (2nd ed., p. 110)

H = the hypothesis, IC = the initial conditions, B = background knowledge, and P = the prediction. The "First Premise" is Condition 2. There is much accompanying explanation pointing out the *modus tollens*, denying the conjunction, and disjunctive

sylogism steps (taught in earlier chapters), as well as a clarification that this "justifying argument" is inductive in nature and that the conclusion is perhaps better expressed as "Thus (inductively), H." or "H is (approximately) true."

The whole approach of the earlier editions is cumbersome. They spend too much time teaching a few principles of formal logic (which may have been gratuitous, depending on what happens in the rest of the course), which are then barely used. The students drown in the details and miss the significant features of scientific reasoning, namely, the role played by the three requirements given above. I question whether exposure to the full, totally rigorous *implicit* inference process used by scientists in justifying and refuting hypotheses is worth this price. The only thing that seemed to work with the students was adopting some "writing-intensive" approaches: requiring them to put their analyses of scientific research reports in short essay form with several opportunities for revision. This process seemed to force the student to understand Conditions 1 and 2, which objective and short-answer testing could not achieve. However, the extra time consumed in doing that, added onto the time spent on the earlier chapters, took too much away from the rest of the semester.

### *The New Version:*

This earlier approach has been completely changed in the Third Edition. One now finds a six-step program:

#### The Program

Step 1. Identify the aspect of the real world that is the focus of study in the case at hand. These are things or processes in the world that you should be able to describe in your own words with, perhaps, just a bit of existing scientific terminology.

Step 2. Identify a theoretical model used to represent the real world.

Describe the model, using scientific terminology as needed. A diagram may be helpful in presenting a model. Indeed, a diagram may be a version of a model.

Step 3. Identify data that have been obtained by observation or experiment involving the real world objects of study.

Step 4. Identify a prediction, based on the model, that says what data should be obtained if the model actually provides a good fit to the real world.

Step 5. Do the data agree with the prediction? If not, conclude that the data provide good evidence that the model, in its present form, does not fit the real world. If the data do agree with the prediction, go on to Step 6.

Step 6. Was the prediction likely to agree with the data even if the model under consideration does not provide a good fit to the real world? This requires considering whether there are other clearly different, but plausible, models that would yield the same prediction about the data. If there are no such alternative models, the answer to the question is "no." In this case, conclude that the data do provide good evidence that the model does fit the real world. If the answer to the above question is "yes," conclude that the data are inconclusive regarding the fit of the model to the real world. (3rd ed., p. 38)

Prior to this program is ample discussion of the important concepts on which it depends, complete with diagrams and case studies. A flow chart, an explanation of why the program works, and three examples to which the steps are applied accompany the program. This program now becomes the linchpin for the rest of the book. A welcome chapter on the history of science applies the program to several classic historical examples (the phases of Venus, Halley's Comet, Phlogiston theory, Mendel's experiments, and plate tectonics). In a chapter on "Marginal Science" the program is applied to several examples (Freudian theory, astrology, Jeane Dixon, Von Daniken, and New Age

beliefs). The program appears again in chapters on evaluating statistical hypotheses and causal hypotheses. Numerous exercises for student practice end each chapter.

Although not explicitly stated in the Third Edition, the three requirements for justifying scientific hypotheses are tidily incorporated in the program. Gone is their *tedious* application in an ungainly, overly-rigorous process of evaluation. This makes possible the synthesizing use of the program described in the previous paragraph—a very important feature of the book. The student is led to a holistic picture of science which neatly ties together its *history*, containing both successes and failures, its *methodology*, including its frequent reliance upon probability and statistics, and its *competitors*, in the form of popular challenges from pseudoscience. Moreover, the student is given the critical tools (and the confidence!) necessary to evaluate a broad range of scientific reports and ample practice on concrete cases.

*Understanding Scientific Reasoning* deserves further praise for the chapters on probability, statistics, causal explanation, and decision-making. It provides one of the clearest, most understandable expositions of these subjects available. This was a virtue of the earlier editions as well. All three editions go deep enough into important concepts in probability and statistics to produce a sound and useful account, while neatly sliding over more technical and potentially distracting problems. Part Three of the book consists of two very short chapters which exhibit the same virtues with respect to elementary decision theory. The emphasis is on both individual and public policy decision-making which depends upon relevant scientific research. Giere's target, once again, is to give the general student with a minimum of math background an easily understood, workable, effective, practically applicable introduction to probability, statistics, and causal explanation in actual scientific practice. He has been supremely successful in that regard,

and the Third Edition has the added merits described above of more clearly tying these areas to the other parts of the book.

#### *A Concern:*

One controversy within the field of critical thinking may imply an objection to Giere's whole program. Several have argued against conceiving of critical thinking as a small collection of skills which apply across many disciplines. John McPeck, for example, argues that *true* critical thinking must be *discipline-specific* because effective thinking about a problem requires a knowledge-base within relevant disciplines. Thus, there can be no general critical thinking skills which apply across many disciplines. It therefore looks as if Giere has mounted at least a semi-challenge to such "no-general-skills" views of critical thinking: he has produced a single, simple program which purports to evaluate critically *all* scientific reasoning without supposing that the person applying the program in a particular instance has any specialized knowledge within the relevant discipline. *If successful*, Giere's program presents the no-general-skills view the following dilemma: either explain the apparent success of a simple, unified set of critical thinking skills among a body of disciplines as diverse as all of the sciences, or broaden the concept of "discipline" (to which skills are supposed to be specific) to something as general as SCIENCE.

In a recent collection of his writings, McPeck is prone to distinguish such things as "historical reasoning" from "mathematical reasoning" (John McPeck, *Teaching Critical Thinking*, Routledge, 1990, p. 90), and he further supports the "discipline-specific monographs by educators ... in physics education and ... biology ... (for) teaching critical thinking in their respective fields." (*Ibid.*, p. 33) In his reply to Richard Paul he comes close to lumping all the sciences together as a "form" or "domain" of "rational discourse," but even

here he makes it clear that rational discussion of a problem demands making the problem precise, and that this precision is achieved only within a particular discipline such as sociology. (*Ibid.*, pp. 118ff.) This makes it seem that McPeck will not gladly take hold of the second horn of the above dilemma.

One could try to escape the dilemma by showing, in one way or another, that Giere has not given us what can be called "true" critical thinking skills, even if they are "successful." However, the skills Giere fastens on are essentially concerned with *understanding* and *evaluating* the *justification* of hypotheses by the evidence. These are arguably core concepts in critical thinking. (We're still assuming for argument purposes that Giere's program is "successful.") But there is perhaps a more fundamental reason why the no-general-skills supporters cannot easily disallow Giere's program. Giere makes it quite clear in several places that his program is not intended to turn students into amateur or professional scientists. They are not learning to do science, rather, they are only learning to evaluate the final results as presented in typical research reports, both popular and professional. These evaluations are done from the standpoint of the average educated citizen concerned about the importance of scientific research to his/her personal welfare or to society. Thus, Giere's sense of "scientific reasoning" is that of a critical process by means of which *anyone*, scientists and non-scientists alike, may evaluate the justification for accepting a particular scientific claim. This should pose a sub-dilemma for critics of a general skills approach since they often speak as if they share something like that view with respect to the goals and purposes of education. For example, McPeck strongly supports the notion of *true* critical thinking as embodied in a broad liberal education, and sees this as very important for society: "In our society, at least since the time of Thomas Jefferson,

the chief purpose of schools has been to produce an informed citizenry, capable of making intelligent decisions about the problems which might face it." (*Ibid.*, p. 29) The irony is that McPeck, if he denies the efficacy of Giere's approach, is in danger of denying the very possibility of what he advocates as the primary goal of education: the possibility that non-scientists can make intelligent decisions about problems to which scientific research is relevant. Thus, it seems that critics of a general skills approach in critical thinking, given their grander hopes for what education may achieve, should be delighted by the success of Giere's program, rather than dismissing it as resting on an ill-conceived concept of critical thinking.

To digress a moment, we might turn Giere's account around as a direct criticism of the no-general-skills view. Perhaps there is a misleading ambiguity in the phrase "scientific reasoning." In one sense, "scientific reasoning" is *any* reasoning scientists employ in going about their business. In the second sense (which is Giere's) "scientific reasoning" is the inference process which justifies or refutes a hypothesis, and which may be evaluated by anyone. In the first sense, "reasoning," "problem-solving" and the like are necessarily discipline-specific—you must be doing real work within a particular discipline. Of course, if you are going to talk like a chemist, and think like a chemist, and problem-solve like a chemist, then you better have the knowledge-base of a chemist. However, if Giere's program works, then you can learn a general framework which substantially benefits critical thought in the sciences, but *which is not itself discipline-specific to any of those sciences*. Confusing these two senses of "reasoning" could lead someone to suppose a knowledge-base *essential* to genuine critical thought. Moreover, one cannot *a priori* rule out the possibility that at least the sciences do hold in common the justificatory sense of "scientific reasoning," and

that this sense is relatively content-independent and not discipline-specific.

This seems to impale no-general-skills advocates on the first horn of the dilemma. Of course, all of the above argument has rested on the working assumption that Giere's program will prove successful. It is a difficult question, not at all addressed in *Understanding Scientific Reasoning*, by what lights such success is to be determined or judged. Supporters of the no-general-skills approach may be so sanguine about the probable failure of any such program that they would not be worried by the conditional dilemma above. Therefore, it is important at this juncture to insist that no question-begging be permitted. There is something very appealing about Giere's approach. My classroom experience, even with the old versions, suggests that the program does work at some level to produce useful critical insights. *Prima facie*, it deserves a fair hearing, and should not be lightly discounted, especially on *a priori* grounds.

But then, what does "success" mean, and how will we judge it? Having students who have completed Giere's program demonstrate better scores on various critical thinking tests would not impress McPeck. He argues that such tests are based upon the ability of students to learn to operate within a myth, rather than showing they've learned "true" critical thinking. (*Ibid.*, pp. 22-25) Furthermore, no currently available tests are sufficiently attuned to the science-oriented skills developed by Giere.

Consequently, I wish to make a modest proposal and enter a plea for tolerance in matters educational. We might try to achieve some measure of the success-in-use of Giere's book along the following lines. Can students taught Giere's method

really apply it to additional cases, and are they able to distinguish between good science, bad science, and pseudoscience with fair consistency over a long period of time and in many different sciences? Do their judgments correlate well or poorly with judgments by practitioners within the relevant disciplines? Does the academic performance of students in science or science-related courses improve after learning Giere's program? It is important to Giere and those in the critical thinking movement to address these and other questions, especially given the broader implications of the no-general-skills view. Demonstrated success by the standards suggested in these questions should give the no-general-skills advocates considerable pause, since it would constitute an existence-proof of general skills applicable to a diverse range of disciplines.

*Understanding Scientific Reasoning* could be used in a number of courses. In a critical thinking course with companion text(s) covering formal and informal logic, it provides an excellent introduction to inductive logic, at least in the sciences. It could also be used in a general-education philosophy of science course with other appropriate readings. The use that would do most justice to the book, however, is as the sole text in a course focused on scientific reasoning. Scientific reasoning represents an important, neglected area within critical thinking which deserves a full-semester's treatment in the curriculum. Giere has given us an excellent book around which to construct such a course.

DAN BOONE  
PHILOSOPHY DEPARTMENT  
INDIANA UNIVERSITY OF PENNSYLVANIA  
INDIANA, PENNSYLVANIA 15705 □