Peer Instruction: A User's Manual

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BOOK REVIEWS

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How Things Work: The Physics of Everyday Life. Louis A. Bloomfield. 706 pp. Wiley, New York, 1997. Price: $46.95 (paper) ISBN 0-471-59473-3. (Reviewed by Richard E. Rothschild.)

We, as members of the scientific community, must take responsibility for reversing the decline in public appreciation for science, and the accompanying alarming growth of pseudo-science. One important step in this direction is the education of students who are not destined for careers in science, and have lost their interest in it. It behooves us to show them that science in general, and physics in particular, is not some esoteric and irrelevant form of magic, but an essential part of our everyday life, and that the vast majority of things we see and use are understandable without ''rocket science.''

Louis Bloomfield's book, *How Things Work: The Physics of Everyday Life*, is a well-considered step in this direction. He has set out to demonstrate that science is all around us, it isn't frightening, and with some effort students can develop and expand their physical intuition as to how things work. Armed with such a perception of their environment, members of our society will be in a better position to understand the scientific issues of the day. *How Things Work* uses everyday objects familar to us all—tape recorders, vacuum cleaners, the ocean—to present basic (and not so basic) physics in a clear and well-conceived manner. The chapters contain wonderful descriptions of how particular devices work, without resorting to equations. This is both a blessing and a curse. The author has managed to explain the inner workings of many things with which we are familar, and I'm sure this will go a long way to dispelling the myth that science is magic. For the student who is not particularly curious, but just appreciates knowing how something works, the general explanations are there. For the more inquisitive student, who may want to go deeper, the underlying physics is missing.

Take the Nuclear Physics chapter as an example. In a clever analogy, nuclear and electroweak forces are described in terms of a toy with a spring and a suction cup. The model is easy to visualize, and the concept of nuclear forces acting over a short range comes across quite well. Lacking, however, is a description of the basic constituents of matter, and a discussion of how their properties determine the characteristics of the elements. An explanation of the periodic table would help the student to understand why some elements act alike—why, for instance, potassium chloride is a substitute for sodium chloride for those needing low sodium diets. A consideration of the various types of nuclear decay would allow extrapolation of what one has learned about uranium to other elements, such as the americium in our smoke detectors. Nowhere is it mentioned that much of the radioactive uranium ends up in the form of common everyday elements such as lead. What are those fission fragments in the illustrations? Half-lives get only a sentence or two, but they explain why many isotopes used in nuclear medicine are over and done in a week or less, eliminating any long-term concern for their presence.

This is an excellent text for what it does, and I would consider it as a supplement in a course for non-physics majors. I would need, however, a main text for the basic physics (a definite cost consideration), or else my lectures would have to be dominated by the presentation of the more fundamental physical basis upon which the examples in *How Things Work* would be drawn. In any event, examples from this book constitute a rich set of discussion topics and specific cases to support the core of basic physics presented in class.

Richard E. Rothschild is a Research Physicist with the Center for Astrophysics and Space Sciences at the University of California, San Diego. His research interests lie in x-ray and gamma-ray astronomy instrumentation and observations of accreting x-ray pulsars, stellar-mass black holes in microquasars, supermassive black holes powering active galaxies, and the origin of gamma-ray bursts. Dr. Rothschild is especially keen on communicating the wonders of the universe and science in general to school children and the general public. He used How Things Work *as a supplement in teaching Concepts in Physics at UCSD, which is aimed at nonscience and non-premed students.*

Peer Instruction: A User's Manual. Eric Mazur. 253 pp. (plus diskettes). Prentice-Hall, Upper Saddle River, NJ, 1997. Price: $21.00 (paper) ISBN 0-13-565441-6. (Reviewed by Mark D. Somers.)

Peer Instruction: A User's Manual by Eric Mazur, a professor of physics at Harvard University, is named after an interactive teaching method that Mazur has developed to help students learn introductory physics. The book is divided into two main parts: a description of Peer Instruction, and the instructional resources needed to implement it. The book begins with an account of Mazur's early teaching experiences and his sense of shock when he discovered that his students could not correctly answer seemingly simple qualitative questions, despite being able to work much more difficult quantitative problems. To his credit, Mazur began to document the disparity between student performance on the two types of questions, by including on his exams paired qualitative and quantitative questions on a single physical concept. He soon discovered that for his students, success in solving traditional physics problems did not imply that they understood the underlying physics. Many physics instructors across the nation have experienced a similar sense of shock when they have come to the same realization. I believe that much of the zeal that characterizes efforts to reform the introductory course is a result.

A typical Peer Instruction class period consists of three to four short (10 minute) presentations that focus on key points. Each presentation is followed by a qualitative ConcepTest on the material that has been presented. ConcepTests are qualitative multiple-choice questions that give students and the instructor a means of assessing what students have learned. Five or more minutes are typically devoted to a ConcepTest, including an opportunity for students to explain their reasoning to one another and an explanation of the correct answer by the instructor. Upon seeing a tally of student answers, the instructor can decide whether to elaborate on the topic or proceed to something new.

Approximately one-third of each class period is devoted to ConcepTests. Mazur omits certain topics from his lectures to compensate. Rather than dropping these topics completely, he includes them in his textbook reading assignments. Mazur holds students accountable for these readings by administering a reading quiz at the beginning of each lecture and by including questions on the omitted topics on his exams.

Mazur discusses several measures he has used to demonstrate the effectiveness of Peer Instruction. The final exams he had written prior to developing Peer Instruction stressed problem solving skills. He administered one of his old finals to a Peer Instruction class to compare the results. The performance of the Peer Instruction class was better than the traditionally taught class. Mazur also continued to give paired qualitative and quantitative questions on each of his exams after he began using Peer Instruction. While performance on the quantitative questions did not change significantly, there was a marked improvement on the qualitative questions. Finally, Mazur measured the performance of his classes before and after he implemented Peer Instruction, using the Force Concept Inventory[1] and the Mechanics Baseline Test,[2] two multiple choice tests that have been well documented nationally. Questions on the Force Concept Inventory are qualitative while quantitative questions are included in the Mechanics Baseline Test. Consistent with the other measures, students in the Peer Instruction classes performed slightly better on the Mechanics Baseline Test than traditionally taught students and significantly better on the Force Concept Inventory.

Approximately two-thirds of the book consists of the instructional resources needed to implement Peer Instruction. A number of reading quiz questions, ConcepTests, and conceptual exam questions are included for each topic of an introductory class, as well as the Force Concept Inventory and the Mechanics Baseline Test. Of these, the ConcepTest multiple choice questions are most valuable since they are at the core of the Peer Instruction method. To be effective, a multiple choice question must include incorrect answers that express the common incorrect beliefs that students bring to a class. Anticipating such errors is quite difficult. Teaching experience and the physics education research literature serve as useful guides. Not infrequently, however, multiple choice questions represent the instructor's ideas, not those of the students. Hence, the resulting tally of student responses must be interpreted with caution. Mazur mentions that he listens to students explain their reasoning to one another in class. Listening to students explain their reasoning in their own words is not only important in determining why students have chosen a particular response, it is also crucial to improving the questions.

The ConcepTests do not always make full use of the physics education research literature. For example, Mazur includes three ConcepTest questions that involve a constant force exerted on a cart that is initially at rest on a frictionless track. The answer to each requires that students recognize that the final speed of the cart is proportional to the magnitude of the force. The literature documents that some students believe that force is *always* proportional to velocity. None of the ConcepTest questions seem directed toward correcting this belief. Of course, this is not a serious problem, because the ConcepTests merely serve as examples for instructors to write their own questions. In fact, Mazur has established a web site[3] where physics instructors from around the nation can submit and exchange ConcepTest questions with one another.

Any instructor of physics, whether knowledgeable of the reform efforts in physics education or not, will find value in Peer Instruction. I believe that the vast majority of physics instructors teach in a manner that they believe is most effective. I also believe that they would willingly change how they teach if they were convinced that the change would result in their students learning more. The sad fact is that there is no consensus among university physics faculty on which teaching method is most effective. I believe that Peer Instruction is a step toward settling the issue, because at its heart is a means of collecting real-time data on what students are learning. To be most useful, however, instructors must not only have real-time feedback on the performance of their own students, they also must be able to compare their students with students being taught in a different manner. Louis Bedell and I are currently developing a system named CyberInteractor[4] that promises to do just that. CyberInteractor is a web-based means of administering multiple-choice questions and collecting responses in a database. Questions can be created and edited over the web. Student responses can be queried under a variety of different criteria.

[1]D. Hestenes, M. Wells, and G. Swackhamer, ''Force Concept Inventory,'' Phys. Teach. **30** (3), 141–151 (1992). *Peer Instructions: A User's Manual* contains a version revised in 1995 by I. Halloun, R. Hake, E. Mosca, and D. Hestenes.

[2]D. Hestenes and M. Wells, ''A Mechanics Baseline Test,'' Phys. Teach. **30** (3), 159–166 (1992).

[3]The Peer Instruction web site is located at http://galileo.harvard.edu.

[4]L. Bedell and M. Somers, ''CyberInteractor—A Teaching and Research Tool,'' Campus-Wide Information Systems (in press).

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Science and Its Ways of Knowing. Edited by John Hatton and Paul B. Plouffe. 150 pp. Prentice-Hall, Upper Saddle River, NJ, 1997. Price: $29.00 (paper) ISBN 0-13-205576-7. (Reviewed by James T. Cushing.)

This collection of 21 previously published essays on the nature of the scientific enterprise is intended as collateral reading for science students, as opposed to providing the basis for a course on the methodology of science. The essays are generally well written (by, among others, Carl Sagan, Robert Pirsig, Stephen Hawking, Karl Popper, Stephen Jay Gould, and Evelyn Fox Keller), but since they are typically only a few pages long, there is little opportunity for any substantive issue to be discussed at length or in depth. The book is an ''easy read,'' intended for students who have never given a thought to what the scientific enterprise actually *is*; nevertheless, it could provide the occasion for some students to become aware that there *are* important, difficult and unresolved questions about the goals, methods and practice of science. However, the reader will probably have to look elsewhere for careful analyses of such matters. Moreover, this book will not necessarily be a helpful guide to such further reading, since there is no bibliography or collection of references (except, of course, the names of the articles or books from which these essays were taken). The editors (whose areas of professional training or research are never made known here), in addition to contributing a General Introduction and two-page introductions to each of the three Parts (''On Scientific Method,'' ''Developing a Theory,'' ''Contexts of Discovery''), do provide reasonable, often helpful, one-paragraph comments preceding each essay, which help to relate the essays to one another.

The reader is exposed to a wide range of views about science, its methods and goals. An important theme that is emphasized repeatedly, both by the editors and by several of the authors, is that the key to science is that it attempts to provide us with *understanding* of our physical universe. Of course, there are several senses in which the term ''understanding'' is used in these essays, and it is important that these be compared, contrasted, analyzed and criticized—something that is not always done explicitly or with care in this book. A crucial distinction that is not sharply drawn is between *laws* (as regularities) and *theories* (as explanations providing understanding).

Perhaps it is not too surprising, in a book that reduces a complex subject to a series of ''sound bites,'' that oversimplifications and ''folklore truths'' (about the history of science) can be found here. Some of these might have been eliminated had there been detailed references given for various claims made—especially when it comes to matters of historical record. For example, the editors (p. vii) repeat the standard thumbnail sketch of the Scientific Revolution as a straightforward overthrow of ''the authority of the Ancients (especially Aristotle, 384–322 B.C.) and of religious dogma (derived largely from Thomas Aquinas, 1225–1274)'' so that, subsequently, an understanding of nature ''must be based on observation/experiment.'' While no one would want to deny this aspect of the rise of modern science and while this claim is hedged with the caveat ''simply put,'' the fact remains that the actual historical record shows that the process was much more complex (and interesting) than this *simple* one-liner suggests. An example of something more disturbing, though, is the repetition (on pp. 72–73) of the standard tale of how Maxwell discovered, or was led to, the displacement current by examining the (near) symmetry of the then-known equations of electricity and magnetism and making them (mathematically) consistent. Even though various versions of this ''derivation'' can be found in several physics textbooks, it is unclear that there is any historical basis for it. [See, for example, A. M. Bork, Am. J. Phys. **31**, 854–859 (1963); J. Bromberg, Arch. Hist. Exact Sci. **4**, 218–234 (1967).] In fact, it seems that Maxwell's conception of the aether (as he understood it at the time) may have played a significant role in his great discovery (something it is convenient to ''forget'' today, when we ''know'' the aether does not exist and we like to present science as finding ''truth''). A detailed bibliographic reference would have allowed the reader to check the truth of this claim.

It is, of course, always a difficult matter to decide where to draw the line between giving students a broad, rather shallow survey of a topic or a field, and presenting so much detail and depth of analysis that he or she is lost and turned off. In much of undergraduate education in the United States we choose the former, especially in ''elective'' or ''optional'' general requirement or distribution courses. This is not the place to attempt to settle the vexing question of which way one ought to go. Let me simply say that the book under review falls into the first category. Still, as I indicated earlier, it might be useful in some situations.

James T. Cushing is Professor of Physics at the University of Notre Dame and works on the foundations, history and philosophy of quantum mechanics. His books include Quantum Mechanics: Historical Contingency and the Copenhagen Hegemony *(University of Chicago Press, Chicago, 1994) and* Philosophical Concepts in Physics *(Cambridge U.P., New York, 1998).*

NO NEW AMAZEMENTS

No, Miller, I don't myself think much of science as a phase of human development. It has given us a lot of ingenious toys; they take our attention away from the real problems, of course, and since the problems are insoluble, I suppose we ought to be grateful for distraction. But the fact is, the human mind, the individual mind, has always been made more interesting by dwelling on the old riddles, even if it makes nothing of them. Science hasn't given us any new amazements, except of the superficial kind we get from witnessing dexterity and sleight-of-hand. It hasn't given us any richer pleasures, as the Renaissance did, nor any new sins—not one! Indeed, it takes our old ones away.

Willa Cather, *The Professor's House* (Vintage Books, New York, 1990; originally published by Alfred A. Knopf, 1925), pp. 54–55.