RESOURCE LETTER

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This is one of a series of Resource Letters on different topics intended to guide college physicists, astronomers, and other scientists to some of the literature and other teaching aids that may help improve course content in specified fields. No Resource Letter is meant to be exhaustive and complete; in time there may be more than one letter on some of the main subjects of interest. Comments on these materials as well as suggestions for future topics will be welcomed. Please send such communications to Professor Roger H. Stuewer, Editor, AAPT Resource Letters, School of Physics and Astronomy, 116 Church Street SE, University of Minnesota, Minneapolis, MN 55455.

Resource Letter EPGA-1: The education of physics graduate assistants

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The intent of this Resource Letter is to provide an introduction to resources for programs for the preparation of physics graduate students for their responsibilities as teachers. © *2000 American Association of Physics Teachers.*

I. INTRODUCTION

This Resource Letter has been undertaken in the hope of providing to those who have the responsibility for the education of physics graduate students—including, of course, the graduate students themselves—an introduction to resources for programs for the preparation of graduate students for their teaching responsibilities. Moreover, since teaching, both formal and informal, is something in which all of us engage in many aspects of our lives, it is hoped that this Resource Letter may be of interest and use to new faculty members and their mentors, and to graduate students who go on to nonacademic positions in which they need to communicate with others in written or oral reports and lectures, or need to provide leadership for persons whose expertise may not be in physics.[1–4]

It should be noted at the outset, however, that this Resource Letter is offered with the strong caveat that experience has clearly shown that there is no Royal Road to success in these matters—no ''one-size-fits-all'' permanent solution to educational problems. As John von Neumann once remarked in another context: ''one should take neither present difficulties nor presently proposed reforms too seriously. To ask in advance for a complete recipe would be unreasonable. We can specify only the human qualities required: patience, flexibility, intelligence.''[5] Moreover, there is more to the education of a physicist and a physics teacher than just physics. Since 1945 when physics and physicists exploded into the consciousness of the world and became a visible part of national budgets, their connections to society have grown stronger and more frequently scrutinized. Some knowledge and understanding of the history and philosophy of science, and of its social and economic relations to the society in which it is embedded has become more than simply desirable. For these reasons the scope of this Resource Letter has intentionally been made rather broad and includes items which, while they may be encountered relatively infrequently, are important and useful both as background and when needed.

The processes whereby one generation passes on its knowledge, experience, and responsibilities to succeeding generations are very old ones, as are the problems associated with so doing. The records of writings, discussions, and pontifications on the subject go back almost to the beginnings of recorded history.[6,7] Moreover, as Jerome Bruner has reminded us:

> each generation must define afresh the nature, direction, and aims of education to assure such freedom and rationality as can be attained for a future generation. For there are changes both in circumstances and in knowledge that impose constraints on and give opportunities to the teacher in each succeeding generation. It is in this sense that education is in constant process of invention.[8]

Over the past few decades we have experienced rapid changes in all aspects of life in our society, many of which have significantly altered the landscape and climate in which our educational systems operate. Social, political, economic, legal, and technological changes, changes in employment patterns, changes in our knowledge and understanding of the learning and teaching processes, and changes in student needs, attitudes, and academic preparation have all generated new opportunities and new constraints. There has been increased societal awareness and concern about the levels of student performance in mathematics and science, and about undergraduate education in general. With an increasing recognition of the value of post-secondary education in our technological world, both the percentage of the population entering higher education and its diversity have been increasing, and higher education, both undergraduate and graduate, has increasingly been the object of criticism and calls for radical change.[9–11]

Research-oriented colleges and universities that have large

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undergraduate and graduate programs and employ graduate students as teaching assistants occupy a strategic position in the educational system. They are sources both for new research results and for new teachers at all levels. They have been the objects of publicly expressed concerns about the relative importance they assign to research and to teaching, and about the need for revising and upgrading instructional programs, including a reassessment and revision of graduate programs, to meet the challenges of changing conditions in society.[12–19]

II. PREPARATION FOR THE ROLE OF TEACHER

Why should we bother with formal programs for the preparation of physics graduate students as teachers? If, as the proverb has it, ''Poeta nascitur, non fit—A poet is born, not made,'' is this not also true of a teacher? This question has been addressed by previous generations and it is instructive and sobering to look at some of their answers.[20]

New answers have evolved in each generation with the evolution of our knowledge and understanding of the processes of learning and teaching. Moreover, recent advances in the cognitive, social and psychological sciences enable one to say that

> The body of research on the cognitive and social processes that underlie the learning and performance of individuals and teams has grown to the point that it is a far better guide to training than is intuition or standard practice. In an era of global competition and information superhighways when the survival value of being able to learn and change is greater than ever before, it is crucial to draw on these resources to enhance training.[21]

In particular, the last two decades have seen the growth of an international community engaged in research in physics education. Systematic study of student understanding has yielded important information about the difficulties that students encounter in learning physics and about effective instructional strategies for addressing these difficulties. There is by now a steadily growing research base that can serve as a resource for the improvement of physics instruction.[22]

III. PROGRAM DESIGN

Any departmental program for preparing graduate students for a role in instruction will have unique features since it will have to take into account local short-term and long-term needs and constraints. In the short-term there is a pressing need to help novice teachers learn ''survival skills'' within the existing system. In addition to fulfilling whatever responsibilities they may have in instruction, graduate assistants are expected to move expeditiously through the sequence of formal courses, examinations, and research work which leads to an advanced degree. Many new graduate assistants, particularly those from other countries, find themselves working under a set of expectations and pressures which exceed in magnitude and differ in kind from any they have previously experienced. But the education of teachers needs to go beyond the short-term goal of minimal survival skills. Just as important is the need to provide for all teachers, and to build into the program itself, the long-term elements of broad perspective, of self-improvement and self-renewal that will keep the teachers, and the system, effective and prepared to take advantage of change as well as to cope with it.

In the design of a new program, or in the revision and updating of an existing program, it is important that careful consideration be given to establishing, at least as a starting point, a clear understanding and a clear statement of what it is that one wishes to achieve. One must give equally careful consideration to the nature and implementation of the feedback and assessment processes necessary to provide pertinent and timely information about how the program is working, the direction in which it is moving, and what changes may be appropriate. It is not only in sailing and space flight that continuing mid-course corrections are essential. Planning must also involve a realistic appraisal of the context in which the program is to be carried out, of the extent and quality of faculty and administrative support, and of available resources of space and of time, of finances, and, especially, of personnel.[23]

An old adage has it that ''There is one thing that each of us knows better than anyone else—that is where the shoe pinches our foot.'' If we wish to understand how graduate students perceive their needs and difficulties, we need to include them in the design and assessment processes from the very beginning. Experience has demonstrated that they can bring to these processes valuable points of view, insights, and creative approaches that might otherwise have gone unrecognized or inadequately appreciated. Likewise, undergraduates who have gone through the courses involved can make significant contributions to the process and to ''reality checks.''

IV. RESOURCES

Resources for programs for the preparation of graduate students for their teaching duties exist at various levels: general, institutional, and disciplinary department—with corresponding levels of specificity. The general literature is truly immense and resources are available in a variety of formats, both print and nonprint, including books, journals, conferences proceedings, bibliographies, workshops, sample programs, and electronic communications. There is also a substantial overlap with programs for new faculty members and, where it appears appropriate, references to such programs have been included.

It is perhaps unnecessary to comment on the great and growing importance of the Internet as a resource. From Applets and audio to e-mail and multimedia to video and virtual reality, the Web makes possible the exchange of information with unprecedented rapidity and scale. Any individual or institution can create websites with numbers of documents and links restricted only by their ability to host them. It opens new opportunities for publication and distribution of both print and nonprint instructional materials, and for interactive discussions and collaborations involving persons who are separated geographically, as in distance learning programs and listserves.

The process of finding material on the Web is being made more manageable by the development of more powerful search engines and of autonomous adaptive intelligent agents.[24] The Web is, however, a resource undergoing very rapid change and web sites appear and disappear or become orphans with disconcerting frequency. Links to references have been provided where available and where the site has remained stable for a substantial period. They are up-to-date as of the time of this writing, but just as books go out of print, these URLs may also.

GENERAL RESOURCES

At the general level the literature on college teaching offers an embarrassment of choices, with new books and articles appearing almost daily. The few items listed here have been chosen as representative of up-to-date and comprehensive resources.

1. *Professional Development of Graduate Teaching Assistants*, edited by M. Marincovich, J. Prostko, and F. Stout (Anker, Bolton, MA, 1998). In the 16 chapters of this book the editors and contributors provide extensive background materials and up-to-date discussions for important aspects of TA programs.

2. *McKeachie's Teaching Tips: Strategies, Research, and Theory for College and University Teachers*, 10th ed., Wilbert J. McKeachie with chapters by G. Gibbs, D. Laurillard, N. V. Chism, R. Menges, M. Svinicki, and C. E. Weinstein (Houghton Mifflin, New York, 1999). http://www.hmco.com/ColCat/college.cgi?FNC=Get Titles_ Aauthorproducts_html_426.0 The tenth edition of this classic volume has much new material and discussion of topics of current interest and importance. The titles of the 28 chapters might well serve as a kind of ''check list'' for items to be considered for inclusion in a locally generated TA Handbook.

3. *Teaching and Learning in the College Classroom*, 2nd ed., edited by K. A. Feldman and M. B. Paulsen (The Association for the Study of Higher Education, Pearson Custom, Needham Heights, MA, 1998). http://www.sscp.com/show/book2.html

4. *Disciplinary Differences in Teaching and Learning: Implications for Practice*, edited by Nira Hativa and Michelle Marincovich, New Directions for Teaching and Learning, No. 64 (Winter 1995) (Jossey-Bass, San Francisco, 1995). http://www.JosseyBass.com/catalog/isbn/0-7879-9909-1/

5. The Journal of Graduate Student Development (New Forums, Stillwater, OK 74076). A quarterly journal ''designed to highlight those aspects of the teaching assistantship which prepare graduate students for the multiple roles they play as teaching assistants as well as for the multiple roles they will play as professionals upon leaving graduate school.'' http://www.newforums.com/prod03.htm

6. ''Research on College Teaching: The Historical Background,'' Wilbert J. McKeachie, J. Educat. Psychol. **82** (2), 189–200 (June 1990).

7. *Styles of Learning and Teaching: An Integrated Outline of Educational Psychology for Students, Teachers, and Lecturers*, Noel Entwistle (Wiley, New York, 1981).

8. *International Handbook of Science Education Part One*, edited by Barry J. Fraser and Kenneth G. Tobin (Kluwer Academic, Dordrecht, 1998).

RESOURCES FOCUSED ON PARTICULAR ASPECTS OF INSTRUCTION

9. *Active Learning: Creating Excitement in the Classroom*, C. C. Bonwell and James A. Eison, ASHE-ERIC Higher Education Report No. 1, 1991 (The George Washington University, School of Education and Human Development, Washington, DC, 1991).

10. *Promoting Active Learning: Strategies for the College Classroom*, Chet Meyers and Thomas B. Jones (Jossey-Bass, San Francisco, 1993). http://www.JosseyBass.com/catalog/isbn/1-55542-524-0/

11. *Collaborative Learning*, Kenneth A. Bruffee (The Johns Hopkins U. P., Baltimore, 1993).

12. *Open to Question: the Art of Teaching and Learning by Inquiry*, W. L. Bateman (Jossey-Bass, San Francisco, 1990). http://www.JosseyBass.com/catalog/isbn/1-55542-268-3/

13. *Software Goes to School: Teaching for Understanding with New Technologies*, D. N. Perkins, J. L. Schwartz, M. M. West, and M. S. Wiske (Oxford U. P., New York, 1995).

14. *Rethinking University Teaching: A Framework for the Effective Use of Educational Technology*, Diana Laurillard (Routledge, London, 1993).

15. *Classroom Assessment Techniques: A Handbook for College Teachers*, 2nd ed., T. A. Angelo and K. P. Cross (Jossey-Bass, San Francisco, 1993). http://www.JosseyBass.com/catalog/isbn/1-55542-500-3/

16. *Motivation for Learning—A Guide for the Teacher of the Young Adult*, Stanford C. Ericksen (Univ. of Michigan, Ann Arbor, 1974).

17. *Selected Legal Issues Relating to Due Process and Liability in Higher Education* (The Council of Graduate Schools, One Dupont Circle, NW, Washington, DC, 1994).
''This booklet was written to provide faculty members and administrators with a basis for understanding some of the legal implications involved in the resolution of conflicts affecting students, faculty, academic programs, and research. The issues addressed are due process and liability concerns, particularly as they relate to a broad spectrum of situations including academic misconduct, termination of employees, sexual harassment, privacy of student records, revocation of degrees, and plagiarism.''

18. *Science Teaching Reconsidered: A Handbook*, NAS/NRC Committee on Undergraduate Science Education (National Academy, Washington, DC, 1997). http://books.nap.edu/catalog/5287.html

19. *Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology*, Committee on Undergraduate Science Education, National Research Council (National Academy, Washington, DC, 1999). http://books.nap.edu/catalog/6453.html

20. *How People Learn: Brain, Mind, Experience, and School*, edited by John D. Bransford, Ann L. Brown, and Rodney R. Cocking, Committee on Developments in the Science of Learning, National Research Council (National Academy, Washington, DC, 1999). http://www.nap.edu/catalog/6160.html

21. *How People Learn: Bridging Research and Practice*, edited by M. Suzanne Donovan, John D. Bransford, and James W. Pellegrino, Committee on Learning Research and Educational Practice, National Research Council (National Academy, Washington, DC, 1999). http://www.nap.edu/catalog/9457.html

Other general articles and books of interest on teaching and teachers include:

22. ''The Place of Teaching in the Research University,'' Frank H. T. Rhodes, in *The Research University in a Time of Discontent*, edited by J. R. Cole, E. G. Barber, and S. R. Graubard (The Johns Hopkins U. P., Baltimore, 1994), pp. 179–189.

23. *A Conversation about Mentoring: Trends and Models*, edited by N. A. Gaffney (The Council of Graduate Schools, One Dupont Circle, NW, Washington, DC, 1995).

24. *Becoming a Critically Reflective Teacher*, Stephen D. Brookfield (Jossey-Bass, San Francisco, 1995). http://www.JosseyBass.com/catalog/isbn/0-7879-0131-8/

25. *The Skillful Teacher: On Technique, Trust, and Responsiveness in the Classroom*, Stephen D. Brookfield (Jossey-Bass, San Francisco, 1990). http://www.JosseyBass.com/catalog/isbn/1-55542-267-5/

26. *Educating the Reflective Practitioner: Towards a New Design for Teaching and Learning in the Professions*, Donald A. Schön (Jossey-Bass, San Francisco, 1987).

27. *Teaching Assistant Training in the 1990's*, edited by J. D. Nyquist, R. D. Abbott, and D. H. Wulff, New Directions for Teaching and Learning Number 39 (Fall 1989) (Jossey-Bass, San Francisco, 1989).

28. ''Effective College Teaching,'' K. Patricia Cross, ASEE Prism. (October 1991), pp. 27–29.

29. Preparing Future Faculty: A National Program of The Association of American Colleges and Universities and The Council of Graduate Schools. There is considerable overlap between the interests and problems of new faculty members and of graduate teaching assistants. A project building on and extending the Preparing Future Faculty program proposes to create model graduate programs to prepare future faculty in five academic disciplines, including physics. Information is available online at http://www.aapt.org/programs/pfpf.html

30. *Adviser, Teacher, Role Model, Friend: On Being a Mentor to Students in Science and Engineering*, Committee on Science, Engineering, and Public Policy, National Academy of Sciences, National Academy of Engineering, Institute of Medicine (National Academy, Washington, DC, 1997). http://books.nap.edu/catalog/5789.html

NATIONAL CONFERENCE PROCEEDINGS

31. *Institutional Responsibilities and Responses in the Employment and Education of Teaching Assistants*, edited by Nancy Van Note Chism (Center for Teaching Excellence, The Ohio State University, Columbus, 1987).

32. *Preparing the Professoriate of Tomorrow to Teach—Selected Readings in TA Training*, edited by J. D. Nyquist, R. D. Abbott, D. H. Wulff, and J. Sprague (Kendall/Hunt, Dubuque, IA, 1991).

33. *The TA Experience: Preparing for Multiple Roles*, selected readings from the 3rd National Conference on the Training and Employment of Graduate Teaching Assistants, edited by Karron G. Lewis (New Forums, Stillwater, OK, 1993).
34. *Teaching Graduate Students to Teach: Engaging the Disciplines, Proceedings of The Fourth National Conference on the Training and Employment of Graduate Teaching Assistants*, edited by T. A. Heenan and K. F. Jerich (1995). Available from UFAS# 1-3-63757. University of Illinois at Urbana-Champaign. Accounting Business Office, 162 Henry Administration Building, 506 South Wright Street, Urbana, IL 61801.
35. *The Professional Apprenticeship: TAs in the 21st Century: The 5th National Conference on the Education and Employment of Graduate Teaching Assistants*, University of Colorado at Boulder, 8–11 November 1995.
36. *Changing Graduate Education. The Sixth National Conference on the Education and Employment of Graduate Teaching Assistants*, University of Minnesota. Twin Cities, 6–9 November 1997. For information, see http://wwwl.umn.edu/ohr/taconference/ A report on this conference by Alan Kalish is on line at http://www.workplace-gsc.com/featuresl/kalish.html

INTERNATIONAL TAs

Although the distribution function for the countries they come from has changed over the years, the number of international physics graduate students remains a substantial fraction of the total physics graduate enrollment, and understanding their individual cultural and educational backgrounds and points of view, as well as the legal aspects of their stay in this country, continues to merit serious attention. In addition to local sources, information may be obtained from national organizations:

37. NAFSA/Association of International Educators, 1307 New York Avenue, NW, Washington, DC 20005-4701. The organization publishes an extensive list of books and articles relating to international students and their problems. NAFSA is on-line at http://www.nafsa.org
38. *International Graduate Students: A Guide for Deans, Faculty, and Administrators* (The Council of Graduate Schools, One Dupont Circle, NW, Washington, DC, 1991).

    ''Designed for deans, faculty, department chairs, and administrators concerned with issues relative to international graduate students. Some topics discussed include recruitment, admissions. English language competence, financial support, and immigration requirements.'' http://www.cgsnet.org/
39. CULTUREGRAMS: Brochures (4 pages) are available for more than 125 areas of the world, providing information on Land and Climate. History, Population, Language, Religion, General Attitudes. Personal Appearance, Greetings, Gestures, Visiting, Eating, Family, Dating and Marriage, Diet, Recreation, Holidays, Commerce, Government, Economy, Transportation and Communication, Education, and Health. They are available from the Publications Division of the David M. Kennedy Center for International Studies, Brigham Young University, P.O. Box 24538, Provo, UT 84602-4538, Tel.: 1-800-528-6279, http://www.culturgram.com/
40. Library of Congress Country Studies: A continuing series of books prepared by the Federal Research Division of the Library of Congress under the Country Studies/Area Handbook Program. This online series currently contains studies of 100 countries. On-line at http://lcweb2.loc.gov/frd/cs/
41. *Cultural Misunderstandings: The French-American Experience*, Reymonde Carroll (University of Chicago, Chicago, 1988). Culture studies contrasting the ways in which the two cultures look at the world.

INSTITUTIONAL RESOURCES

Almost every university and college has an ''Office of Faculty and TA Development'' or a ''Center for Teaching and Learning'' which provides campus-wide programs of assistance to faculty and TAs. Most institutions also have an ''Office of International Student Affairs'' and an ''Office of Disability Services'' which provide useful information and support in these areas. Significantly, most of these organizations have web sites on their college or university servers. Listings at the University of Kansas and at Dalhouse University provide links to about 200 such programs in 44 states in the US and listings to many centers in other countries.[25] The resources thus available include institutional Handbooks for TAs, syllabi for TA training courses, bibliographies on teaching and learning, book reviews, and occasional papers on a wide variety of relevant subjects. These sites are an important source of information and resources, and web surfing among them can uncover much useful material most of which may be freely downloaded.[26]

DISCIPLINARY RESOURCES

Among the sciences physics has been in the forefront in responding to the need for change. In the past decade or so there have been many innovative curriculum developments, national conferences and workshops, and national proposals for the reform and revitalization of instructional programs.

Physics education conference proceedings

42. *The Changing Role of Physics Departments in Modern Universities: Proceedings of ICUPE*, edited by Edward F. Redish and John S. Rigden (American Institute of Physics Conference Proceedings 399, College Park, MD, 1997). The two volumes of the proceedings of this international conference on physics education provide a panoramic view of important developments of the past decade or so, and a section with sample classes of some of the new instructional developments.
43. *Conference on the Introductory Physics Course: On the Occasion of the Retirement of Robert Resnick*, edited by Jack Wilson (Wiley, New York, 1997). These proceedings focus primarily on introductory level courses.
44. *PER Conference 98. Physics Education Research Conference Proceedings 1998*, edited by T. C. Koch and R. G. Fuller (Univ. of Nebraska, Lincoln, 1999).

    ''We see this document as a snapshot of the Physics Education Research community in the United States, as of the summer of 1998. The proceedings includes a printed version of almost all the talks from the conference, as well as an appendix with historical information and summaries of the activities of the U.S. PER groups.'' http://physics.unl.edu/perc98
45. Physics Education Research Conference 1999 Program. http://www.physics.umd.edu/rgroups/ripe/perg/perc/
46. *Thinking Physics for Teaching: Proceedings of an International Conference on Thinking Science for Teaching: The Case of Physics*, edited by C. Bernardini, C. Tarsitani, and M. Vicentini (Plenum, New York, 1995). http://www.wkap.nl/bookcnt.htm/0-306-45192-1
47. *Research in Physics Learning: Theoretical Issues and Empirical Studies. Proceedings of an International Workshop*, Bremen, Germany, 4–8 March 1991, edited by R. Duit, F. Goldberg, and H. Niedderer (IPN, Kiel, Germany, 1992).
48. *Cooperative Networks in Physics Education Proceedings of the Oaxtepec Conference*, edited by J. Barojas (American Institute of Physics Conference Proceedings 173, College Park, MD, 1988).
49. *Research on Physics Education, Proceedings of the First International Workshop*, La Londe Les Maures, France, edited by G. Delacôte, A. Tiberghien, and J. Schwartz (Éditions du CNRS, Paris, 1983).
50. Conferences sponsored by GIREP: International Research Group on Physics Teaching, (http://pef.pef.uni-lj.si/~girep/) are published in English and include *The Many Faces of Teaching and Learning Mechanics* 1984 (Holland); *COSMOS—An Educational Challenge* 1986 (Denmark); *Energy Alternatives—Risk Education* 1989 (Hungary); *Teaching about Reference Frames—From Copernicus to Einstein* 1991 (Poland); *Light and Information* 1993 (Portugal); *Teaching the Science of Condensed Matters and New Materials* 1995 (Italy); *New Ways of Teaching Physics* 1996 (Slovenia); *Hands-on Experiments in Physics Education* 1998 (Germany).

Books and articles on physics teaching

51. *A Guide to Introductory Physics Teaching*, Arnold B. Arons (Wiley, New York, 1990).

52. *Teaching Introductory Physics*, Arnold B. Arons (Wiley, New York, 1997). This book subsumes its predecessor (Ref. **51**) and provides an additional section of problems.
http://www.wiley.com/college/math/phys/cg/sales/arons/arons.html

53. *Teaching Introductory Physics: A Source Book*, Clifford E. Swartz and Thomas Miner (Springer-Verlag, New York, 1998).
http://www.springer-ny.com/catalog/np/apr98np/1-56396-320-5.html

54. *Peer Instruction: A User's Manual*, Eric Mazur (Prentice Hall, Englewood Cliffs, NJ, 1997).
http://www.prenhall.com/books/esm_0135654416.html

55. *Tutorials in Introductory Physics and Homework Manual*, Lillian C. McDermott and Physics Education Group, University of Washington (Prentice Hall, Englewood Cliffs, NJ, 1997). Table of Contents on-line at http://www.prenhall.com/books/esm_0139566406.html

56. *Just-In-Time Teaching: Blending Active Learning with Web Technology*, G. M. Novak, E. T. Patterson, A. D. Gavrin, and W. Christian (Prentice Hall, Englewood Cliffs, NJ, 1999).
http://www.prenhall.com/books/esm_0130850349.html

57. *On Teaching Physics*, edited by M. N. Phillips (AAPT, 1979).

58. *Small Group Teaching in Undergraduate Science*, edited by Jon Ogborn (Heinemann Educational Books, London, 1977).

59. ''Reading the equations and confronting the phenomena—The delights and dilemmas of physics teaching,'' Robert H. Romer, Am. J. Phys. **61** (2), 128–142 (1993).

Journals, Newsletters, and Listserves

American Journal of Physics
http://www.aapt.org/pubs_catalog/Am.J.Phys.html
Physics Education Research: A Supplement to the American Journal of Physics
http://www.aapt.org/pubs_catalog/per/per.html
The Physics Teacher
http://www.aapt.org/pubs_catalog/tpt/tpt.html
Journal of College Science Teaching
http://www.nsta.org/pubs/jcst/
Journal of Research in Science Teaching
http://www3.interscience.wiley.com/catalog/jorder.cgi?action=journal&id=00224308
Physics Education News (PEN)
http://www.aip.org/enews/pen/subpen.html
The Physics Alliances Newsletter
http://www.physics.rutgers.edu/~lindenf/aps/
Newsletter of the Forum on Physics Education of the American Physical Society
Forum web site at http://www.aps-fed.org
Physics Education, Institute of Physics, London
http://www.iop.org/Journals/pe
International Journal of Science Education
http://www.tandfdc.com/JNLS/sed.htm
Cognition and Instruction
http://www.erlbaum.com/html/969.htm
Science & Education. Contributions from History, Philosophy and Sociology of Science and Mathematics. http://www.wkap.nl/jrnltoc.htm/0926-7220
Physics in Perspective, edited by J. S. Rigden and R. H. Stuewer, Birkhäuser Verlag
http://www.birkhauser.ch/journals/1600/1600_tit.htm
E-mail Discussion Groups For Physics Education: Directory on line at http://www-hpcc.astro.washington.edu/scied/physics/physlists.html
Tomorrow's Professor Listserv: Tomorrow's Professor: Preparing for Academic Careers in Science and Engineering, Richard M. Reis, Stanford University
http://cis.stanford.edu/structure/tomprof/listserver.html

Physics education research resources

The field of physics education research has become well established in the physics community during the past decade. A recent Resource Letter, PER-1: Physics Education Research, provides an extensive critical bibliography and an invaluable guide to the field. It is recommended that it be consulted in connection with this Resource Letter.

60. ''Resource Letter: PER-1: Physics Education Research,'' L. C. McDermott and E. F. Redish, Am. J. Phys. **67** (9), 755–767 (1999).

Other recent developments may be found in the journals referenced above, and in

61. *Connecting Research in Physics Education with Teacher Education*, edited by Andrée Tiberghien, E. Leonard Jossem, and Jorge Barojas (an I.C.P.E. Book, 1998, 1999).
http://www.physics.ohio-state.edu/~jossem/ICPE/BOOKS.html

DEPARTMENTAL PROGRAMS

As has been noted previously, there is no ''one-size-fits-all'' permanent solution for departmental programs for preparing graduate students for a role in physics instruction. Each program will have unique features answering to the details of local circumstances, local curricula, and the myriad of other local short-term needs and constraints. It is, however, a commonly observed characteristic of successful programs that, while answering to the local conditions, they involve graduate students as partners in the enterprise, that they have strong departmental and institutional support, and that they have effective feedback mechanisms for continuing self-assessment and revitalization. It is apparent also that the most important and valuable resource for any such program lies in the imagination, creativity, empathy, patience, persistence, and just plain hard work of those who design, create, and work to sustain and improve it.

Departmental programs tend to fall into two general categories:

(a) programs directly connected with a specific course or course sequence, usually at the introductory level, in which many of the graduate assistance teach, and
(b) programs of a more general character involving formal course work in physics education, often as a part of an advanced degree program in the field.

In contrast to the volume of material at the general and the institutional levels, relatively little has been published about individual departmental programs in either category. Perhaps this may be so because, in some sense, helping someone to learn how to teach well is more easily done than said, and the process is more of an apprenticeship in which, as Picasso put it. ''What I do not know how to do, I learn by doing.''

62. *Physics Departments in the 1990s. Topical Conference Series April 30–May 2, 1993*, edited by G. M. Crawly and B. V. Cheery (American Association of Physics Teachers (TC-07), College Park, MD, 1993). Brief descriptions of TA training programs in the physics departments of four universities, and discussions on mentoring new faculty, are provided on pp. 58–78.

63. ''Teaching teaching assistants at UT-Austin,'' L. C. Shepley, in *Conference on the Introductory Physics Course: On the Occasion of the Retirement of Robert Resnick*, edited by Jack Wilson (Wiley, New York, 1997), pp. 229–232.

64. ''Training the Teaching Assistant: Matching TA Strengths and Capabilities to Meet Specific Program Goals,'' F. Lawrenz, P. Heller, R. Keith, and K. Heller, J. Coll. Sci. Teach. **22** (2), 106–109 (November 1992).

65. ''TA Orientation Syllabus, Fall 1999,'' University of Minnesota Physics Education Research and Development Group. http://www.physics.umn.edu/groups/physed/TA_Orientation/TA99Syllabus.htm

Publications of a previous generation which still preserve their interest:

66. ''Suggestions for beginning college physics teachers,'' Dana Roberts, Phys. Teach. **19** (5), 305–309 (1981).

67. ''Tips for TAs,'' Michael J. Bozak, Phys. Teach. **21** (1), 21–28 (1983).

68. ''Use of observers in physics sections,'' K. J. Casper, Am. J. Phys. **41** (11), 1274–1277 (1973).

69. ''Observer in the classroom,'' K. A. Carroll, Am. J. Phys. **41** (11), 1277–1282 (1973).

70. ''Instant replay and the graduate teaching assistant,'' F. S. Mozer and S. M. Napell, Am. J. Phys. **43** (3), 242–244 (1975).

71. ''Hawthorne effect and quality teaching: Training graduate teaching assistants to teach,'' A. Armenti, Jr. and G. F. Wheeler, Am. J. Phys. **46** (2), 121–124 (1978).

FORMAL COURSES IN PHYSICS EDUCATION

In contrast to training programs keyed to ongoing individual introductory level courses, programs for preparation of graduate students for a career in teaching and research in physics education may include formal courses and seminars at the graduate level which run for a semester or more. Such courses offer the opportunity for a deeper and more comprehensive view of physics education. At this level also the opportunity presents itself for the active involvement of the graduate students as colleagues as well as students. In his Millikan Award Lecture ''Teaching and Learning,'' Frank Oppenheimer remarked that ''There are two things that teachers must do well. They can set up environments that are conductive to learning, and they can help students get unstuck. It is difficult to be more specific.''[27]

Individual courses will answer to local needs and boundary conditions, but actively involving the graduate students in the design and implementation of the course, and having the course itself model for them some of the many ways in which one can ''set up environments that are conducive to learning'' and ''help students get unstuck'' are useful points of departure.

The old basic questions ''What shall I teach?'' and ''How shall I teach it?,'' and the more specific questions that follow from them, are germane at all levels of instruction and suggest a wide variety of topics for study and discussion in the areas of, for example, curriculum development, learning and teaching styles, student and teacher characteristics, motivations and attitudes, instructional methodologies and technologies, lectures and lecture demonstrations, tutorials, cognitive studies, concept formation, problem solving, laboratory work and laboratory safety, examinations, assessment, evaluation and other feedback mechanisms, mentoring, the history, philosophy, cultural and societal aspects of physics, the interactions of physics with and its relations to other disciplines, and research in the field of physics education.

With an increasing number of programs in physics education research appearing in physics departments around the country more such courses are coming into being. Here again there is no ''one-size-fits-all,'' and syllabi for such courses necessarily reflect the philosophies and viewpoints of the individual programs.[28]

This section presents a smorgasbord of references to topics from which to pick and choose. As was mentioned in the Introduction, the selection has intentionally been made rather broad and includes items which, while they may be encountered relatively infrequently, are important and useful both as background and when needed.

The reader is also reminded of Ref. **42**: The Changing Role of Physics Departments in Modern Universities: Proceedings of ICUPE, edited by Edward F. Redish and John S. Rigden (American Institute of Physics Conference Proceedings 399, College Park, MD, 1997), and Ref. **60**: Resource Letter: PER-1: Physics Education Research, L. C. McDermott and E. F. Redish, Am. J. Phys. **67** (9), 755–767 (1999), as print sources of major importance for additional references and examples.

Curriculum development

A comparison of the number of Physics Abstracts for 1949 with that for 1999 documents the enormous and continuing expansion of our knowledge and understanding of the physical world that has occurred since the end of World War II. Corresponding changes in the Physics Abstracts classification scheme illustrate the profound changes in the way physicists classify physical phenomena and conceptualize the relations among them. Equally profound have been the developments in communications, information, and pedagogical technologies. All of these changes have contributed to new problems for curriculum development in each succeeding generation, problems which are made increasingly difficult because while our knowledge has continued to expand, the time available for formal instruction has not. Maxwell's comment that ''Now a days we have too much to teach and too little time to teach it''[29] has even more relevance today than when he made it in 1856.

The history of conferences and projects related to college and university physics curricula in the era of the sixties and early seventies contained in the reports of the Commission on College Physics provides insight into the successes and failures of the many curricular ideas and reforms of that period both for introductory level courses and for physics major curricula.[30] In the decade of the 1990's a national curriculum project. The Introductory University Physics Project (1UPP). undertook to encourage new approaches and increased diversity in introductory physics courses.

72. ''The Introductory University Physics Project 1987–1995: What has it accomplished?'' L. A. Coleman, D. F. Holcomb, and John S. Rigden Am. J. Phys. **66** (2), 124–137 (1998). This paper reviews the history of the project and its accomplishments. In their ''Final Comments,'' pp. 136–137, the authors discuss lessons for the future and quote Bruner: ''a curriculum is a thing in balance that can not be developed first for content, then for teaching method, then for visual aids, then for some other particular feature.''[31]

As a part of the project one of the authors developed a useful set of ''filters'' for assessing the suitability of a given topic for inclusion in an introductory level course.

73. ''Guest Comment: Filters for choosing topics for the introductory physics course,'' D. F. Holcomb Am. J. Phys. **61** (11), 969–970 (1993). A sampling of other curricular projects was presented in a Special Edition of the Education Outreach publication of the American Physical Society and is available online at http://www.aps.org/educ/edout9.html

74. ''Introductory Physics Reform in the Traditional Format: An Intellectual Framework,'' Kenneth J. Heller, Newsletter of the Forum on Education of the American Physical Society, Summer 1999, pp. 7–9; http://webs.csu.edu/~bisb2/FEdnl/heller.htm

75. *Individual Study in Undergraduate Science H.E.L.P. Curriculum*; http://ivc.uidaho.edu/natnova/pdf/undergradscience.pdf
76. ''Experiments in teaching captives,'' H. R. Crane, Am. J. Phys. **34** (9), 799–807 (1996).

Feedback: Examinations and assessment

> It is amusing the way your best-laid plans go wrong in dealing with a class or an audience. An examination often turns into an examination of the teacher's ability to ask questions clearly. You never can tell what you have said or done till you have seen it reflected in other people's minds. Robert Frost.[32]

77. ''A Retrospect on Making and Judging,'' in *Towards a Theory of Instruction*, Jerome Bruner (Harvard U. P., Cambridge, MA, 1966), pp. 163–171.
78. *Inside the Black Box: Raising Standards through Classroom Assessment*, Paul Black and Dylan Wiliam, School of Education, King's College, London (1998).
79. ''Examinations: Powerful agents for good or ill in teaching,'' E. M. Rogers, Am. J. Phys. **37** (10), 954–962 (1969).
80. ''The real test bias: Influences of testing on teaching and learning,'' Norman Fredericksen, Am. Psychol. **39** (3), 193–202 (1984).
81. ''On maximizing the information obtained from science examinations, written and oral,'' John R. Platt, Am. J. Phys. **29** (2), 111–122 (1961).

Lectures and lecture demonstrations

Lectures are of many different types and may serve different purposes: from the formal lecture given by a recipient of the Nobel Prize, and popular lectures on physics designed to entertain as well as to instruct an audience, to interactive lectures which actively involve the members of the audience. One chooses a style appropriate to the occasion and the audience.

82. ''How to address the APS,'' Karl K. Darrow, Phys. Today **34** (12), 25–29 (1981).
83. ''Advice to lecturers,'' Lewis Elton, Phys. Today **34** (5), 128 (1982).
84. ''Advice to beginning physics speakers,'' James C. Garland, Phys. Today **44** (7), 42–45 (1991).
85. ''What's wrong with those talks?'' N. David Mermin, Phys. Today **45** (11), 9–11 (1992).

These papers provide advice on addressing one's professional peers.

86. *Peer Instruction: A User's Manual*, Eric Mazur (Prentice Hall, Englewood Cliffs, NJ, 1997). This book discusses interactive lectures for introductory level courses.

Lecturers preparing graphical material may wish to consult

87. *The Visual Display of Quantitative Information*, Edward R. Tufte (Graphics, Cheshire, CT, 1983).

PIRA, The Physics Instructional Resource Association, has developed a very extensive bibliography of Lecture Demonstrations.

88. The PIRA Demonstration Bibliography. Online at http://www.physics.ncsu.edu/pira/
''This Demonstration Bibliography contains about 7500 entries including all of Sutton, Freier & Anderson, Meiners, Hilton, Am. J. Phys., The Video Encyclopedia of Physics Demonstrations, the Minnesota Demonstration Handbook, a few articles from the Physics Teacher, and listings of the PIRA 200, PIRA 500, and PIRA 1000 demonstrations.''
89. TAP-L, a list-serve, provides a site for discussion of lecture demonstration topics; http://www.physics.ncsu.edu/pira/tap.html
90. Online Physics Demonstration Manuals. A collection of links to many universities in the U.S.A. on line at http://www.physics.ncsu.edu/pira/demosite.html
91. PSRC Demonstration Resources, An AAPT Resource, online at http:www.psrc-online.org
92. *The Art and Science of Lecture Demonstration*, Charles Taylor (Institute of Physics, Bristol, 1988).
93. *Why Toast Lands Jelly-Side Down: Zen and the Art of Physics Demonstrations*, Robert Ehrlich (Princeton U. P., Princeton, NJ, 1997).
94. *Turning the World Inside Out and 174 Other Simple Physics Demonstrations*, Robert Ehrlich (Princeton U. P., Princeton, NJ, 1990).
95. ''Resource Letter: PhD-1: Physics demonstrations,'' J. A. Davis and B. G. Eaton, Am. J. Phys. **47**, 835–840 (1979).
96. *Clouds in a Glass of Beer: Simple Experiments in Atmospheric Physics*, C. F. Bohren (Wiley Science, New York, 1987).

Students

97. *Student's Reactions to Undergraduate Science*, edited by J. Bliss and Jon Ogborn (Heinemann Educational Books, London, 1977).
98. ''Students do not think physics is 'relevant.' What can we do about it?'' H. R. Crane, Am. J. Phys. **36** (12), 1137–1143 (1968).
99. ''On the problem of making science attractive for women and Minorities: An annotated bibliography,'' J. M. Yarrison-Rice, Am. J. Phys. **63** (3), 203–211 (1995).
100. ''Semantics in teaching introductory physics,'' H. Thomas Williams, Am. J. Phys. **67** (8), 670–680 (1999).
101. ''Physics students' epistemologies and views about knowing and learning,'' W. M. Roth and A. Roychaudhury, J. Res. Sci. Teach. **31** (1), 5–30 (1994).
102. ''Professors as physics students: What can they teach us?'' S. Tobias and R. R. Hake, Am. J. Phys. **56** (9), 786–794 (1988).
103. *They're Not Dumb, They're Different: Stalking the Second Tier*, Sheila Tobias (Research Corporation, Tuscon, AZ, 1990).

Students with disabilities

The Individuals with Disabilities Education Act of 1990 (IDEA) and the Americans with Disabilities Act of 1990 (ADA) have brought about a growing trend toward inclusion—educating students with disabilities in the same setting as their nondisabled peers. Local Offices of Disability Services can provide information about legal requirements and liabilities.

104. ''Teaching college physics to a blind student,'' Michelle Parry, Mark Brazier, and Ephriam Fischbach, Phys. Teach. **35** (8), 470–474 (1997).
105. ''Teaching astronomy for the blind: Providing a lecture and laboratory experience,'' George F. Spagna, Jr., Am. J. Phys. **59** (4), 360–363 (1991).
106. ''Accommodating mobility-impaired students in physics laboratories,'' Ronald M. Frinks, Phys. Teach. **21** (8), 536–537 (1983).
107. ''Acoustics for deaf physics students,'' Harry G. Lang, Phys. Teach. **19** (4), 248–249 (1981).
108. ''Physics labs for the blind,'' James Baughman, Jr. and Dean Zollman, Phys. Teach. **15** (6), 339–342 (1977).
109. ''A physical science course for the visually impaired,'' Bruce Weems, Phys. Teach. **15** (6), 333–338 (1977).
110. ''Teaching physics to the deaf,'' Harry G. Lang, Phys. Teach. **11** (9), 527–531 (1973).
111. ''Testing Students with Disabilities,'' K. F. Geisinger and J. F. Carlson, ERIC Digest ED391984 95 (ERIC Clearinghouse on Counseling and Student Services, Greensboro, NC); http://www.ed.gov/databases/ERIC_Digests/ed391984.html
112. ''Questions To Ask When Evaluating Tests,'' L. M. Rudner, ERIC/AE Digest, ED385607 April 94 (ERIC Clearinghouse on Assessment and Evaluation, Washington, DC).
113. Nemeth Braille Code for Mathematics and Science Notation. http://www.purdue.edu/odos/TAEVIS/N_code.htm

Laboratories and laboratory safety

> The laboratory work should form the backbone of the physics course. The experimental work should aim to bring clearly before the pupil the physical meaning of laws and processes, and enable him to organize and ap-

ply such knowledge. From: *How to Teach Physics*, Rogers D. Rusk (Lippincott, Philadelphia, 1923).

114. *Lab Focus 93: Current Initiatives in High School and Undergraduate Physics Laboratories*, edited by R. W. Peterson, K. B. Johnson, and J. L. Hansberger (AAPT, College Park, MD, 1994).
115. *Apparatus for Teaching Physics*, edited by K. C. Mamola (AAPT, College Park, MD, 1998).
116. *An Introduction to Scientific Research, Revised edition*, E. Bright Wilson, Jr. (Dover, New York, 1991). A classic volume.
117. *Teaching Physics Safely: Some Practical Guidelines in Seven Areas of Common Concern in Physics Classrooms*, edited by Richard W. Peterson (OP-19 AAPT). This project of the AAPT Committee on Apparatus suggests safety habits for electrical hazards, lasers and light, pressurized and vacuum systems, ionizing radiation, fires, toxic materials, and mechanical dangers.

Problem solving and sources for problems

118. *Problem Solving and Comprehension*, 6th ed., Arthur Whimbey and Jack Lochhead (Lawrence Erlbaum, New York, 1999).
119. ''Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems,'' W. J. Leonard, R. J. Dufresne, and J. P. Mestre, Am. J. Phys. **64** (12), 1495–1503 (1996).
120. ''Understanding and Teaching Important Scientific Thought Processes, Millikan Lecture 1994,'' F. Reif, Am. J. Phys. **63** (1), 17–32 (1995).
121. ''Comparing problem solving performance of physics students in inquiry-based and traditional introductory physics courses,'' B. Thacker, E. Kim, K. Trefz, and S. M. Lea, Am. J. Phys. **62** (7), 627–633 (1994).

In contrast to the traditional ''end-of-chapter'' problems in which only information necessary to solve the problem is given, there is a growing interest in what have been called ''estimation problems'' or ''back-of-the envelope problems'' or ''Fermi questions.'' There are some often overlooked sources from which ideas for such problems may be obtained both at the introductory level and at more advanced levels.

122. University of Maryland Fermi Problems Site. An extensive collection on line at http://www.physics.umd.edu/rgroups/ripe/perg/fermi.html
123. ''The Back of the Envelope,'' Edward M. Purcell. A series of problems and solutions which appeared in the *American Journal of Physics* from August 1987 through June 1988.
124. ''Search for Simplicity,'' Victor F. Weisskopf. A series of discussions and examples which appeared in the *American Journal of Physics* from January 1985 through October 1986.
125. ''Of atoms, mountains, and stars: A study in qualitative physics,'' Victor F. Weisskopf, Science **187** (4177), 605–612 (1975).
126. The ''New Problems'' department of the *American Journal of Physics* presents interesting, novel problems for use in undergraduate physics courses beyond the introductory level.
127. *Reconciling Physics with Reality*, A. B. Pippard (Cambridge U. P., London, 1972).
128. *How Things Work: A Collection of* ''How Things Work'' *Columns from The Physics Teacher 1983–1991*, H. R. Crane (AAPT, College Park, MD, 1994).
129. ''Teaching problem solving—A scientific approach,'' Frederick Reif, Phys. Teach. **19** (5), 310–316 (1981).
130. ''Teaching problem solving through cooperative grouping, Part 1: Group versus individual problem solving,'' P. Heller, R. Keith, and S. Anderson, Am. J. Phys. **60** (7), 627–636 (1992).
131. ''Teaching problem solving through cooperative grouping, Part 2: Designing problems and structuring groups,'' P. Heller and M. Hollabaugh, Am. J. Phys. **60** (7), 637–644 (1992).
132. ''Context Rich Problems: On-line Archive,'' University of Minnesota Physics Education Research Group. http://www.physics.umn.edu/groups/physed/Research/CRP/on-lineArchive/ola.html
133. ''Response of the Oersted Medallist,'' H. Richard Crane, Am. J. Phys. **45** (7), 599–601 (1977). The subtitle ''The Real World Connection'' reflects H. R. Crane's concerns with a number of the fundamental problems of physics teaching.
134. ''Better teaching with better problems,'' H. R. Crane, Phys. Today **22** (3), 161 (1969).
135. ''Problems for introductory physics,'' H. R. Crane, Phys. Teach. **7**, 371 (1969); **8**, 182 (1969).
136. *The Flying Circus of Physics With Answers*, Jearl Walker (Wiley, New York, 1977).
137. *Riddles in Your Teacup: Fun with Everyday Scientific Puzzles*, 2nd ed. P. Ghose and D. Home (IOP, Bristol, 1994).

Other areas from which ''Real Life'' problems may be drawn include:

138. *Physics of the Body*, 2nd ed., J. R. Cameron, J. G. Skofronick, and R. M. Grant (Medical Physics, Madison, WI, 1999).

and books on sports

139. *The Physics of Golf*, 2nd ed., Theodore P. Jorgensen (Springer-Verlag, New York, 1999). http://www.springer-ny.com/physics/jorgensen/index.html
140. *The Physics of Skiing: Skiing at the Triple Point*, D. Lind and S. P. Sanders (Springer-Verlag, New York, 1996). http://www.springer-ny.com/aip/backlist/titles/physics_of_skiing.html
141. *The Physics of Baseball*, Robert Kemp Adair, 2nd rev. ed. (HarperCollins, New York, 1995). http://www.harpercollins.com/catalog/redir.aspl?0060950471
142. ''How would a physicist design a tennis racket?'' Howard Brody, Phys. Today **48** (3), 26–31 (1995).
143. *The Physics of Sports*, edited by A. Armenti, Jr. (American Institute of Physics, College Park, MD, 1992).
144. *Newton at the Bat: The Science in Sports, Revised Edition*, edited by E. W. Schrier and W. F. Allman (Scribner, New York, 1987).
145. ''Resource Letter PS-1: Physics of sports,'' C. Frohlich, Am. J. Phys. **54** (7), 590–593 (1986).
146. *Sport Science: Physical Laws and Optimum Performance*, Peter J. Brancazio (Simon & Schuster, New York, 1984).
147. *The Dynamics of Sports: Why That's The Way The Ball Bounces*, David F. Griffing (Mohegan, Loudenville, OH, 1982).

For extraterrestrial sources for material for problems, see

148. *The Physics of Star Trek*, Lawrence M. Krauss (Basic Books, New York, 1995).
149. *Beyond Star Trek*, Lawrence M. Krauss (Harper Perennial, New York, 1998).

History, philosophy, and cultural aspects

In 1928 in Gottingen, while working with Born, he (V. F. Weisskopf) expressed his fear that the life in science, as it seemed to him, would isolate him from the concerns of humanity. But Born calmed him down saying 'Stay in physics. You will see how deeply the new physics is involved with human affairs.' From: *Physics and Society—Essays in Honor of Victor Frederick Weisskopf by the International Community of Physicists*, edited by V. Stefan (AIP/Springer-Verlag, New York, 1998), p. 24.

150. ''Special Issue: The Physics Community and the Wider World,'' Phys. Today **52** (3) (1999).
151. American Institute of Physics Center For History of Physics, ''A mission to preserve and make known the history of modern physics and allied fields including astronomy, geophysics, optics, and the like.'' http://www.aip.org/history/
152. *The Physicists: The History of a Scientific Community in Modern America, With a New Preface by the Author*, Daniel J. Kevles (Harvard U. P., Cambridge, MA, 1995).
153. *Physics History from AAPT Journals*, edited by Melba N. Phillips (American Association of Physics Teachers, College Park, MD, 1985).
154. *History of Physics*, S. P. Weart and M. N. Phillips (American Institute of Physics, College Park, MD, 1985).
155. *The Life and Times of Modern Physics: History of Physics II*, edited by Melba N. Phillips (American Institute of Physics, College Park, MD, 1992).
156. ''Resource Letter HP-1: History of physics,'' Stephen G. Brush, Am. J. Phys. **55** (8), 683–691 (1987).

157. *More Things in Heaven and Earth, A Celebration of Physics at the Millennium*, edited by Benjamin Bederson (APS/Springer-Verlag, New York, 1999).
158. *Physics in the 20th Century*, C. Suplee, edited by J. S. Rigden and J. R. Franz (Abrams, New York, 1999).
159. *The Birth of Particle Physics*, edited by L. M. Brown and Lillian Hoddeson (Cambridge U. P., Cambridge, 1983).
160. *Experiment and Theory in Physics*, Max Born (Dover, New York, 1956).
161. *Reflections on Experimental Science*, Martin L. Perl (World Scientific, New York, 1996).
162. *Physics in Perspective*, Physics Survey Committee–National Research Council, Vol. I (1972), Vol. IIA (1972), Vol. IIB (1973), Vol. IIC (1973) (National Academy of Sciences, Washington, DC). This multivolume survey of physics is a major source of information about physics, and about its interfaces with other sciences and with society in the era of the 1960's and 1970's. Sections on Physics and Education are to be found in Vol. I. Sec. II, Physics in Education and Education in Physics, pp. 723–805, and in Vol. IIA, Sec. XIII, Education, pp. 1133–1263.
163. *Little Science, Big Science...And Beyond*, Derek J. Desolla Price (Columbia U. P., New York, 1986).
164. *Einstein: A Centenary Volume*, edited by A. P. French (Harvard U. P., Cambridge, 1979).
165. *Who Got Einstein's Office*? Ed Regis (Addison-Wesley, Reading, MA, 1987).
166. *Niels Bohr: A Centenary Volume*, edited by A. P. French and P. J. Kennedy (Harvard U. P., Cambridge, MA, 1985).
167. *Galileo Galilei*, James MacLachlan (Oxford U. P., Oxford, 1999).
168. ''Toward preparing students for change: A critical discussion of the contribution of the history of physics in physics teaching,'' W. Jung, Sci. Educ. **3** (2), 99–130 (1994).
169. *The Structure of Scientific Revolutions, Third edition*, Thomas S. Kuhn (Univ. of Chicago, Chicago, 1996).
170. *Explaining Science: A Cognitive Approach*, R. N. Giere (Univ. of Chicago, Chicago, 1988).
171. *The Ring of Truth: An Inquiry into How we Know What we Know*, Philip and Phylis Morrison (Random House, New York, 1987).
172. *Introduction to Concepts and Theories in Physical Science, Second Edition*, Gerald Holton and Stephen G. Brush (Addison–Wesley, Reading, MA, 1973).
173. *Concepts of Force: A Study in the Foundations of Dynamics*, Max Jammer (Harvard U. P., Cambridge, MA, 1957).
174. ''Resource Letter PhM-1: Philosophical foundations of classical mechanics,'' Mary Hesse, Am. J. Phys. **32** (12), 905–911 (1964).
175. *Doing Physics: How Physicists Take Hold of the World*, Martin H. Krieger (Indiana U. P., Bloomington, 1992).
176. *How Experiments End*, Peter Galison (Univ. of Chicago, Chicago, 1989).
177. *The Relevance of Physics*, Stanley L. Jaki (Univ. of Chicago, Chicago, 1966).

> ''Physics has become the most powerful instrument at man's disposal for seeking out and revealing the hidden facts of inanimate nature. Are its methods and its insights equally relevant to other areas of human concern?''

178. *An Introduction to Science Studies: The Philosophical and Social Aspects of Science and Technology*, John Ziman (Cambridge U. P., Cambridge, 1987).
179. *Of One Mind: The Collectivization of Science*. John Ziman (American Institute of Physics, College Park, MD, 1995).
180. ''Philosophy of science,'' R. S. Cohen, Sci. Educat. **3**, 393–407 (1994).
181. *Science: The Center of Culture*, I. I. Rabi (World Publishing, Cleveland, OH, 1970).
182. *First You Build a Cloud and Other Reflections on Physics as a Way of Life*, K. C. Cole (Harcourt Brace, New York, 1999). Includes a useful bibliography.
183. *The Thermodynamics of Pizza: Essays on Science and Everyday Life*, H. J. Morowitz (Rutgers U. P., New Brunswick, NJ, 1991).
184. ''Artistic Invitations to the Study of Physics, Millikan Lecture,'' Alan Holden, Am. J. Phys. **36** (12), 1082–1087 (1968).
185. ''Poetry for physicists,'' S. Tobias and L. S. Abel, Am. J. Phys. **58** (9), 816–821 (1990).
186. ''Resource Letter SL-1: Science and literature,'' Marjorie Nicholson, Am. J. Phys. **33** (3), 175–183 (1965).
187. ''Resource Letter TLA-1: Technology, literature, and art since World War II,'' William H. Davenport, Am. J. Phys. **38** (4), 407–414 (1970).
188. ''Resource Letter TLA-2: Technology, literature, and the arts, contemporary,'' William H. Davenport, Am. J. Phys. **43** (1), 4–8 (1975).
189. ''Resource Letter ColR-1: Collateral reading for physics courses,'' Alfred M. Bork and Arnold B. Arons, Am. J. Phys. **35** (2), 71–78 (1967).
190. *Breaking the Science Barrier: How to Explore and Understand the Sciences*, Sheila Tobias and Carl T. Tomizuka (College Entrance Examination Board, New York, 1992).
191. *Talks to Teachers on Psychology and to Students on Some of Life's Ideals*, William James (Dover, New York, 1962).
192. *Issues in Science Education: Science Competence in a Social and Ecological Context*, edited by T. Husen and J. P. Keeves (Pergamon, New York, 1991).
193. National Academy Of Sciences/National Research Council: Resources for involving scientists in education.[33] http://www.nas.edu/rise/
194. ''Science Education Through the Eyes of a Physicist,'' T. Schultz (National Academy Of Sciences/National Research Council). http://www.nas.edu/rise/backg2d.htm

Physics humor and fun:

''A little nonsense now and then is relished by the wisest men.'' American Proverb

195. IOP Physics Web: Web Links: Humor and Fun http://physicsweb.org/resources/paw.phtml?k=Humor+and+Fun&f=1&t=k

CODA

The reader is once again reminded that it is possible in a Resource Letter such as this to provide pointers to only a small fraction of the resources needed to design and build a successful program, and that there is no ''one-size-fits-all'' answer. The crucial elements and the crucial decisions must come from the designers and users themselves. In this connection it is also worth repeating that the involvement of graduate—and undergraduate—students as active participants, contributors, and stakeholders in the process can pay major dividends, and be an important and exciting educational experience for all concerned.

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[1]*Preparing Physicists for Work*, edited by Amy Schlaub (American Institute of Physics, Career Services Division, College Park, MD, 1997).
[2]''Communication in industrial research laboratories,'' Frank E. Jamerson, Am. J. Phys. **50** (10), 896–898 (1982).
[3]''Realities of the Physics Job Market,'' Roman Czujko, in *Physics Graduate Education for Diverse Career Options*, edited by Judy R. Franz (American Center for Physics, College Park, MD, 1995), pp. 40 and 43.
[4]''What Work Requires Of Schools: A Scans Report For America 2000,'' The Secretary's Commission On Achieving Necessary Skills (U.S. Department Of Labor, June 1991); http://www.ttrc.doleta.gov/SCANS/work.html
[5]''Can we survive technology?'' John von Neumann, Fortune (June 1955) p. 106 ff.

[6]*Three Thousand Years of Educational Wisdom, Second Edition, Enlarged*, edited by Robert Ulich (Harvard U. P., Cambridge, MA, 1975).

[7]*Eight Hundred Years of Physics Teaching*, George Bishop (Fisher Miller, North Waltham, Hants, U.K., 1994).

[8]*Toward a Theory of Instruction*, Jerome S. Bruner (Harvard U. P., Cambridge, MA, 1966), Chap. 2: Education as Social Invention, pp. 22 ff.

[9]*A Nation at Risk: The Imperative for Educational Reform*, The National Commission on Excellence in Education (U.S. Government Printing Office, Washington, DC, 1983).

[10]*College: The Undergraduate Experience in America*, Ernest L. Boyer (Harper and Row, New York, 1988).

[11]''How Are We Doing? Tracking the Quality of the Undergraduate Experience, 1960s to the Present,'' George D. Kuh, Rev. Higher Educat. **22** (2), 99–120 (Winter 1998); http://www.press.jhu.edu/journals/review_of_higher_education/v022/22.2kuh.html

[12]*Faculty Development in a Time of Retrenchment*, The Group for Human Development in Higher Education (Change Magazine, New Rochelle, NY, 1974).

[13]''Reforming the Graduate Schools,'' in *The Academic Revolution*, Christopher Jencks and David Riesman (Doubleday, New York, 1968), pp. 510–543.

[14]''Preparation for College Teaching,'' in *Challenges to Graduate Schools*, Ann M. Heiss (Jossey-Bass, San Francisco, 1970), pp. 227–241.

[15]*Scholarship Reconsidered: Priorities of the Professoriate*, Ernest L. Boyer (The Carnegie Foundation for the Advancement of Teaching, Princeton, NJ, 1990).

[16]*Renewing the Promise: Research-Intensive Universities and the Nation: A Report Prepared by the President's Council of Advisors on Science and Technology* (U.S. Government Printing Office, Washington, DC, 1992).

[17]*The Research University in a Time of Discontent*, edited by J. R. Cole, E. G. Barber, and S. R. Graubard (The Johns Hopkins U.P., Baltimore, 1994).

[18]*Reinventing Undergraduate Education: A Blueprint for America's Research Universities*, The Boyer Commission on Educating Undergraduates in the Research University; http://notes.cc.sunysb.edu/Pres/boyer.nsf/

[19]''Déjà vu all over again,'' Jules B. LaPidus, Liberal Educat. **79** (2), 10–15 (Spring 1993).

[20]The physics community has long recognized that something more is required.

In a Report by the Educational Committee of the American Physical Society entitled ''The Teaching of Physics: With Especial Reference to the Teaching of Physics to Students of Engineering'' (presented to the Council 24 February 1922, ordered printed 21 April 1922), the committee has the following comment (p. 55):

> ''Theory of Teaching. This topic has been left to the last, since it is probable that opinions on it will differ. It is a frequent remark of experienced teachers of college subjects that the work of new instructors often suffers from a lack of some elementary knowledge of the theory and art of teaching. College teachers are supposed to be born, not made. Each stumbles through the series of mistakes of his predecessors, and at length by experience, discussions, and reading, comes to some more or less adequate knowledge of the practical psychology of his profession. Some say that this is the only way of becoming a competent teacher. But we believe that many broad-minded and experienced teachers do not subscribe to this view. It is true that writers on the theory of education have usually been concerned chiefly with the work of elementary and secondary schools. It may also be true that the college teacher, because of his superior education and intelligence, stands in less need of formal instruction in methods of teaching. Allowing for these factors, it is, we believe, nevertheless true that many experienced teachers could be of service to novices by drawing their attention to certain broad principles of instruction on which practically all college teachers of experience would agree, and to some mistakes and fallacies into which most beginners fall. There are psychologists and lecturers on the theory of education in American colleges who could be of great service in this connection by brief articles, of not too technical a nature, on the practical psychology of college teaching. It is, of course, true that little or no attempt has been made to do this for other subjects of college instruction. But this does not show that the thing is not in itself desirable and possible. Moreover, since it is generally admitted that physics is an especially difficult subject to teach, it should be the one for which such aids to intelligent teaching are especially necessary, and it might well lead the way.''

In his article ''Physics is Physics,'' on the first page of the first issue of the American Physics Teacher in February 1933, F. K. Richtmyer comments:

> ''The responsibility, then, for training young teachers lies. I believe, with the subject-matter departments. It is the duty of the older, more experienced teachers in a department to impress the idea upon the beginner, by precept, example and friendly counsel, that teaching is a serious business, requiring careful study; that his obligations to his students, present and future, require that he should make every effort to profit by the opportunity to acquire teaching experience under expert guidance; and that to this end he should strive to adopt teaching methods best suited to his own personal characteristics, to his students, and to the subject matter taught'' (p. 4). ''It is frequently remarked that we American teachers teach far too much in comparison with our European colleagues: that it is better for the student if we expect him to take some initiative in his reading, studying and thinking. This criticism of the American method is, I believe, justified; but I do not think that the criticism applies to our training of college teachers. I do not think we train them too much! Perhaps we overdo the matter of leaving them to their own devices'' (p. 5).

[21]*Learning, Remembering, Believing: Enhancing Human Performance*, edited by D. Druckman and R. A. Bjork, Committee on Techniques for the Enhancement of Human Performance, Commission on Behavioral and Social Sciences and Education, National Research Council (National Academy, Washington, DC, 1994), p. 306; http://books.nap.edu/catalog/2303.html

[22]''Teaching physics: Figuring out what works,'' E. F. Redish and R. Steinberg, Phys. Today **55** (1), 24–30 (1999) and references therein.

[23]See, for example, ''Institutional Impediments to Effective Training,'' in *Learning, Remembering, Believing: Enhancing Human Performance*, edited by D. Druckman and R. A. Bjork, Committee on Techniques for the Enhancement of Human Performance, Commission on Behavioral and Social Sciences and Education, National Research Council (National Academy, Washington, DC, 1994), pp. 295–306; http://books.nap.edu/catalog/2303.html

[24]In a paper entitled ''The diameter of the Internet'' (http://xxx.lanl.gov/abs/cond-mat?9907038), Albert, Jeong, and Barabasi note that while the number of documents on the Internet already exceeds 300 million, any two randomly selected Web pages are, on average, 18 hyperlinks or clicks apart. They predict also that were the number of documents to increase by 1000%, the number of hyperlinks required would only grow from 18 to 20 and that if an intelligent robot agent could interpret and follow the relevant Web links, it could find information much faster than the current generation of search engines. Progress in producing such autonomous intelligent agents has been reported in, e.g., ''A Personal News Agent that Talks, Learns and Explains,'' D. Billsus and M. Pazzani, Proceedings of the Third International Conference on Autonomous Agents (Agents '99), Seattle, 1–5 May 1999 (http://www.ics.uci.edu/~dbillsus/papers/agents99-news.pdf) and in ''The Daily Learner: An intelligent online newspaper that learns and explains,'' http://dailylearner.ics.uci.edu/

[25]Online University Teaching Centers in the USA http://eagle.cc.ukans.edu/~cte/OtherSites.html
Dalhousie University's Instructional Development and Technology Sites Worldwide
http://www.dal.ca/~oidt/ids.html#AN

[26]A random sample of such centers and of ''Handbooks for TAs'' in the USA can be found at the following URLs.
Carnegie Mellon University:
http://www.cmu.edu/provost/teaching/center.html
http://www.cmu.edu/provost/teaching/bestpractices.htm#REFERENCES
Massachusetts Institute of Technology:
The Torch or the Firehose: A Guide to Section Teaching, Arthur P. Mattuck (1995)
http://www.mit.edu/afs/athena.mit.edu/org/o/odsue/tll/www/torch-table.html
Pennsylvania State University:
http://www.psu.edu/idp_celt/PST/pst.shtml
University of Massachusetts at Amherst:
http://www.umass.edu/cft/handbook.html
University of Texas at Austin:
www.utexas.edu/academic/cte/
University of California at Santa Barbara:
http://id-www.ucsb.edu/IC/TA/ta.html
University of California at San Diego:

http://www-ctd.ucsd.edu/toc.htm
University of California at Berkeley:
http://www.grad.berkeley.edu:5900/gsi/
Queen's University at Kingston (Canada):
http://www.queensu.ca/idc/HandBook/tofc.html
University of Washington:
http://depts.washington.edu/cidrweb/TAITATraining.html
The Ohio State University:
http://www.acs.ohio-state.edu/education/ftad/services.html
University of Michigan Ann Arbor:
http://www.umich.edu/~crltmich/gsi_work2.html

[27]''Teaching and learning,'' Frank Oppenheimer, Am. J. Phys. **41** (12), 1310–1313 (1973).

[28]Accounts of the course content may often be obtained from the faculty member involved, but few have been made available on the Web. See, for example, ''Physics 708: Graduate Seminar in Teaching College Physics for Physicists,'' Department of Physics, University of Maryland; http://www.physics.umd.edu/rgroups/ripe/perg/gsrl.html

[29]J. C. Maxwell, ''Inaugural Lecture at Marischal College, Aberdeen, 3 November 1856,'' *The Scientific Letters and Papers of James Clerk Maxwell, Volume I 1846–1862*, edited by P. M. Harman (Cambridge U.P., Cambridge, 1990), p. 428.

[30] ''Progress Report Commission on College Physics,'' Am. J. Phys. **32** (6), (1964); ''Report of The Commission on College Physics,'' Am. J. Phys. **34** (9), Part 2 (1966); ''Report of The Commission on College Physics,'' Am. J. Phys. **36** (11), Part 2 (1968); for other discussions of physics curricula in this era see ''Undergraduate Curricula in Physics: A Report on the Princeton Conference on Curriculum S,'' E. Leonard Jossem, Am. J. Phys. **32** (6), 491–497 (1964); ''Less May Be More,'' Philip Morrison, Am. J. Phys. **32** (6), 441–457 (1964); ''Dialogs Concerning Some Old Sciences—The Seattle Interdisciplinary Conference,'' E. Leonard Jossem, Am. J. Phys. **32** (9), Part 2, 867–869 (1966); '''New Physics' and the Minnesota Conference on New Materials for Introductory Physics Courses for Science and Engineering Majors, 6–8 May 1965,'' Peter G. Roll, Am. J. Phys. **34** (9), Part 2, 872–884 (1966); ''Teaching physics for related sciences and professions,'' A. P. French and E. L. Jossem, Am. J. Phys. **44** (12), 1149–1159 (1976); ''The rise and fall of PSI in physics at MIT,'' Charles P. Friedman, Stanley Hirschi, Malcolm Parlett, and Edwin F. Taylor, Am. J. Phys. **44** (3), 204–211 (1976); ''An example of an informative 'postmortem' of a type much needed in higher education,'' ''Autopsy,'' Paul R. Camp, Am. J. Phys. **53** (10), 949–952 (1985). Another example from the University of Maine.

[31]*Toward a Theory of Instruction*, Jerome S. Bruner (Harvard U. P., Cambridge, MA, 1966), p. 164.

[32]In ''Education by Presence,'' an interview with Frost published in the Christian Science Monitor, 24 December 1925, reprinted in *Robert Frost, Poetry and Prose*, edited by E. C. Lathem and L. Thompson (Holt, Reinhart and Winston, New York, 1972).

[33]In an address to the AAAS Science Policy Seminar Series, 16 September 1998. Rita Colwell, Director of the National Science Foundation, remarked

> ''Furthermore, we cannot expect the task of science and math education to be the sole responsibility of *K* through 12 teachers while scientists and graduate students live only in their universities and laboratories. There is no group of people who should feel more responsible for science and math education in this nation than our scientists and scientists-to-be.'' ''In fact. I would say that America's continuing leadership will depend more on the caliber of its human resource than on any other resource. It will not be enough to have a top layer of scientific elite, and another of mediocrity below. And the situation is really worsened by widespread public science illiteracy.''

COACHING

The longer I'm associated with coaching, the more strongly I'm convinced that coaching is motivation. Another way of saying it is, coaching is teaching, and I don't think you can teach effectively for any length of time unless you can motivate your players to want to learn. In developing a motivational philosophy, I think there are probably two factors a coach needs to keep in mind. First he should be open-minded in terms of willingness to consider new techniques, since not everyone responds to the same stimuli, and even the best techniques can grow stale through overuse. Second, he should have the determination to continue to try to ''reach'' boys and girls who do not respond to his initial efforts. Many different approaches to motivation are described and discussed in *Coaching and Motivation*, for the simple reason that the subject requires broad treatment. There is not single, simple way of motivating everyone, just as there is no single formula for winning. Many of my own ideas on motivation are included in the present volume but I am not so vain as to suggest that they will work for everyone. You have to do what you do best, and in the best way you can.

Jerry Tarkanian in the Forward to *Coaching and Motivation: A Practical Guide to Maximum Athletic Performance*, W. E. Warren (Prentice Hall, Inc., NJ, 1983).

There are two kinds of things that teachers must do well. They can set up environments and situations that are conducive to learning, and they can help students get unstuck. It is difficult to be more specific.

Frank Oppenheimer, *Teaching and Learning*, The AAPT Millikan Lecture, Am. J. Phys. 41, (12), 1310–1313 (1973).