Suggested Readings and Materials in Physics Education

This is a guide to literature and materials on physics education research, active learning and research-based curriculum. This is not meant to be a complete survey of the literature, but rather suggestions for readings that expand on the material in the textbook and the instructor's manual. McDermott and Redish's resource letter on physics education research is available on-line and should soon appear in the *American Journal of Physics* for those interested in a more thorough survey of the physics education research literature.

Arons' *Teaching Introductory Physics* is an especially useful resource for physics teachers. Drawing on Arons' extensive classroom experience, this is an excellent reference on the nature of student difficulties in introductory physics classes and on teaching methods he has found to be effective. It is a very broad introduction to the issues of introductory physics instruction as well as a source of more conceptual problems to supplement the text. This book includes Arons' previously published instructor references *A Guide to Introductory Physics* and *Homework and Test Questions for Introductory Physics Teaching* with some additions.

References marked with a * are good entry points into the literature.

General Readings on Physics Education and the Introductory Physics Class

A.B. Arons, "Phenomenology and logical reasoning in introductory physics classes," *American Journal of Physics* **50** (1), 13-20 (1982).

* A. Arons, "Student patterns of thinking and reasoning," *The Physics Teacher* in three parts: **21**, 576-581 (1983); **22**, 21-26 (1984); **22**, 88-93 (1984).

A.B. Arons, *Teaching Introductory Physics* (John Wiley & Sons, New York, 1997).

D. Hammer, "More than misconceptions: Multiple perspectives on student knowledge and reasoning, and an appropriate role for education research," *American Journal of Physics* **64**, 1316-1325 (1996). Available online at http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html.

D. Hestenes, "Toward a modeling theory of physics instruction," *American Journal of Physics* **55**, 440-454 (1987).

D. Hestenes, "Who needs physics education research?" *American Journal of Physics* **66**, 465-467 (1998).

* L.C. McDermott, "Millikan Lecture 1990: What we teach and what is learned—Closing the gap," *American Journal of Physics* **59** (4), 301-315 (1991).

L.C. McDermott, "Bridging the gap between teaching and learning: The role of research," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 139-166.

L.C. McDermott and E.F. Redish, "RL-PER1: Resource letter on physics education research," *American Journal of Physics* **67** (9), 755–767(1999). Also available online at http://www.phys.washington.edu/groups/peg/pubs.html and at http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html.

E.F. Redish and J.S. Rigden (Editors.), *American Institute of Physics Conference Proceedings No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education* (American Institute of Physics Press, Sunnyvale NY, 1997).

* E.F. Redish, "Millikan Lecture 1998: Building a science of teaching physics," *American Journal of Physics* **67** (7), 562-573 (1999). Available online http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html.

E.F. Redish and R.N. Steinberg, "Teaching physics: Figuring out what works," *Physics Today* **52** (1), 24-30 (1999). Available online at http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html.

F. Reif, "Scientific approaches to science education," *Physics Today* **39** (11), 48-54 (1986).

F. Reif, "Instructional design, cognition, and technology: Applications to the teaching of scientific concepts," *Journal of Research in Science Teaching* **24** (4), 309-324 (1987).

* S. Tobias, *They're not dumb, They're different* (Research Corporation, Tucson AZ, 1990).

* A. Van Heuvelen, "Learning to think like a physicist: A review of research-based instructional strategies," *American Journal of Physics* **59** (10), 891-897 (1991).

Research-based Physics Curricula & Materials

This is a list of research-based materials that can be used to supplement Serway and Beichner, *Physics for Scientists and Engineers*, in addition to the ancillary materials.

ALPS Kits/Active Physics

Materials:

The *Active Learning Problem Sheets* (the *ALPS Kits*) include inexpensive worksheets that can be used to enhance student conceptual understanding and problem solving expertise. They emphasize multiple representations of physical situations and encourage active participation of students in all parts of their instruction. Materials are included for interactive lecture activities. The first encounter with a topic is qualitative followed by quantitative analysis. The *ALPS Kits* are a comprehensive product to supplement introductory physics courses that emphasize problem solving (college calculus-based physics and algebra-based physics, and high school honors and AP physics).

A. Van Heuvelen, *ALPS: Mechanics* (Vol. 1), *Electricity and Magnetism* (Vol. 2) (Hayden-McNeil Publishing, Westland MI, 1994).

ActivPhysics is a comprehensive multimedia-problem package designed to supplement introductory physics courses that emphasizes problem solving (college calculus-based physics and algebra-based physics, and high school honors and AP physics). The Mac and PC product includes two parts each with a CD and workbook. Active Physics covers all areas of physics.

A. Van Heuvelen, *ActivPhysics Workbook* (Addison Wesley Interactive, 1997).

Related Readings:

A. Van Heuvelen, "Overview, Case Study Physics," *American Journal of Physics* **59**, 898-907 (1991).

A. Van Heuvelen, "Overview, Case Study Physics," online at http://www.ed.gov/offices/OPE/FIPSE/LessonsII/newmexst.html (1993).

A. Van Heuvelen, "Using interactive simulations to enhance conceptual development and problem solving skills," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 1119-1136.

R. Gautreau and L Novemsky, "Concepts first: A small group approach to physics learning," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 575-582.

Activity-Based Physics (ABP)

Activity-Based Physics is a multi-university project to sustain and enhance current efforts to render introductory physics courses more effective and exciting at both the secondary and college level. This program represents a multi-university collaborative effort by a team of educational reformers to use the outcomes of physics education research along with flexible computer tools to promote activity-based models of physics instruction.

ABP Tutorials and Alternative Physics Problems

The *ABP Tutorials* are microcomputer-based laboratory (MBL), video-based laboratory (VBL), and Quantitative Tutorials in the style of University of Washington tutorials (see *Tutorials in Introductory Physics* listed below). The tutorials are recitation replacement activities where student groups work on research-based worksheets designed to promote conceptual understanding. The *ABP tutorials* are available online along with *Alternative Homework Assignments*, *Thinking Problems in Physics*, and a collection of *Estimation Problems* for University physics classes. These are supplemental problems designed to help students improve their conceptual understanding and reasoning skills.

Materials:

Available from the University of Maryland Physics Education Research Group's website at http://www.physics.umd.edu/rgroups/ripe/perg/abp/.

Related Articles:

* E.F. Redish, J.M. Saul, and R.N. Steinberg, "On the effectiveness of active-engagement microcomputer-based laboratories," *American Journal of Physics* **65** (1), 45-54 (1997). Available online at http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html.

R.N. Steinberg, M.C. Wittmann, and E.F. Redish, "Mathematical Tutorials in introductory physics," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 1075-1092.

Interactive Lecture Demonstrations (ILD), Tools for Scientific Thinking (TST), and/RealTime Physics (RTP)

These are three microcomputer-based lab (MBL) supplemental curricula that have been demonstrated to improve student understanding of basic Newtonian concepts of force and motion. Instant feedback helps students relate the motion of objects and their graphical representations. The curricula can be used to supplement a standard lab curriculum (*TST*), replace all or most of a standard lab curriculum (*RTP*), or be used for enhanced demonstrations in lecture (*ILD*). Although the materials are designed to work with Vernier's ULI computer interface, they can also be used with PASCO's MBL products.

Materials:

R. Thornton and D. Sokoloff, *Tools for Scientific Thinking Motion and Force (Vol. 1), Heat and Temperature* (Vol. 2) (Vernier Software, Portland OR, 1992 and 1993).

D. Sokoloff, R. Thornton, and P. Laws, *RealTime Physics—Module 1: Mechanics, Module 2: Heat and Thermodynamics* (John Wiley & Sons, New York, 1999).

D. Sokoloff, R. Thornton, and P. Laws, *RealTime Physics—Electric Circuits* (Vernier Software, Portland OR, 1999).

R. Thornton and D. Sokoloff, *MBL Interactive Lecture Demonstrations—Motion, Force, and Energy* (Vernier Software, Portland OR, 1999).

Related Articles:

R.K. Thornton, "Tools for Scientific Thinking: Learning physical concepts with real-time laboratory tools," in *The Conference on Computers in Physics Education: Proceedings*, edited by E.F. Redish and J.S. Risley (Addison-Wesley, New York, 1990), 177-189.

* R.K. Thornton and D.R. Sokoloff, "Learning motion concepts using real-time microcomputer-based laboratory tools," *American Journal of Physics* **58** (9), 858-867 (1990).

R.A. Morse, "Acceleration and net force: An experiment with the force probe," *The Physics Teacher* **31** (4), 224-226 (1993).

R.A. Morse, "Constant acceleration: Experiments with a fan driven dynamics cart," *The Physics Teacher* **31** (8), 436-438 (1993).

R.K. Thornton, "Using large-scale classroom research to study student conceptual learning in mechanics and to develop new approaches to learning," in *Microcomputer-Based Labs: Educational Research and Standards*, edited by R.F. Tinker, Series F, Computer and Systems Sciences **156** (Springer Verlag, Berlin, Heidelberg, 1996), 89-114.

D.R. Sokoloff and R.K. Thornton, "Using Interactive Lecture Demonstrations to create an active learning environment," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 1061-1074.

R.K. Thornton and D.R. Sokoloff, "RealTime Physics: Active learning laboratory," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 1101-1118.

* D.R. Sokoloff and R.K. Thornton, "Using interactive lecture demonstrations to create an active learning environment," *The Physics Teacher* **35** (6), 340-347 (1997).

Workshop Physics

The Workshop Physics curriculum is an integrated guided-inquiry laboratory-based curriculum that replaces the traditional lecture/recitation/laboratory format. Students work in groups with computers and MBL equipment to study physical situations and test mathematical models. The students learn physics by doing physics rather than just reading or hearing about it. Workshop Physics is a one-year curriculum replacement for class sizes of up to thirty students.

Materials:

P.W. Laws, *Workshop Physics Activity Guide* (John Wiley & Sons, New York NY, 1997). An instructor's version is available from CD-ROM from Wiley. Additional information is available from the project website at Dickinson College at http://physics.dickinson.edu/.

Related Articles:

P. Laws, "Calculus-based physics without lectures," *Physics Today* **44** (12), 24-31 (December, 1991).

H. Pfister and P. Laws, "Kinesthesia-1: Apparatus to experience 1-D motion," *The Physics Teacher* **33** (4), 214-220 (1995).

* P. Laws, "Millikan Lecture 1996: Promoting active learning based on physics education research in introductory physics classes," *American Journal of Physics* **65** (1), 13-21 (1997).

P.W. Laws and P.J. Cooney, "Workshop Physics: A sample class on oscillations, Determinism, and Chaos," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 959-972.

P.W. Laws, "A new order for mechanics," in *Proceedings of the Conference on the Introductory* Physics Course, Rensselaer Polytechnic Institute, Troy, NY, May 20-23, 1992, edited by Jack Wilson (Wiley, New York, 1997), 125-136.

P.W. Laws, P.J. Rossborough, and F.J. Poodry, "Women's responses to an activity-based introductory physics program," *Physics Education Research: A Supplement to the American Journal of Physics* **67** (7), S32-S38 (1999).

Bridging

An approach that helps students build a reasoning bridge from their preconceptions to the physics view using intermediate "bridging" analogies, microscopic models, demonstrations, and experiments. The materials go over several bridging lessons on Newton's laws of motion. The materials also discuss several student preconceptions in this area.

Materials:

C.W. Camp and J.J. Clement, *Preconceptions in Mechanics: Lessons Dealing with Students' Conceptual Difficulties* (Kendall/Hunt Publishing Co., Dubuque IA, 1994).

Related Articles:

* J. Minstrell, "Explaining the 'at rest' condition of an object," *The Physics Teacher* **20**, 10-14 (1982).

J. Clement, D. Brown, and A. Zeitsman, "Not all preconceptions are misconceptions: Finding anchoring conceptions for grounding instruction on students' intuition," *International Journal of Science Education* **11** (special issue), 554-565 (1989).

J. Clement, "Using bridging analogies and anchoring intuitions to deal with student preconceptions in physics," *Journal of Research in Science Teaching* **30** (10), 1241-1257 (1993).

Cooperative Group Problem Solving and Problem Solving Labs

This curriculum emphasizes the teaching of expert-like problem-solving and collaborative learning skills. The students are taught an expert-like problem-solving strategy like GOAL in lecture and practice using it in groups of three on challenging "context rich" problems in recitation and open-ended lab questions in lab. Because the collaborative groups distribute the thinking load among the members of a group, students can successfully apply the problem solving strategy early in the course to problems on which most beginning students would initially fail. Special attention is paid to help the groups to help them together as a team.

Materials:
University of Minnesota's Cooperative Group Problem Solving curriculum materials are available online at **http://www.physics.umn.edu/groups/physed/**. Additional material is available upon request.

Related Readings:
* P. Heller, R. Keith, and S. Anderson, "Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving," *American Journal of Physics* **60** (7), 627-636 (1992).

P. Heller and M. Hollabaugh, "Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups," *American Journal of Physics* **60** (7), 637-644 (1992).

P. Heller, T. Foster, and K. Heller, "Cooperative group problem solving laboratories for introductory courses," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 913-934.

Just-in-Time Teaching

Just-in-Time Teaching (*JiTT*) is a teaching and learning strategy comprised of two elements: classroom activities that promote active learning and World Wide Web resources that are used to enhance the classroom component. Active learning assignments and enrichment materials are delivered to the students over the web. They respond to these assignments electronically. A subset of these electronic submissions provides immediate feedback to the instructors concerning the state of the class' progress. These assignments, due in the morning a few hours before class, are used to adjust the classroom activities to suit the students' needs. One aspect that has application outside of the *JiTT* curriculum is *Physlets*, java applets that can be used to deliver web-based interactive simulations and problems to students. Note that web delivery means that students can access these activities on any computer that can access the web.

Materials:
G.M. Novak, E.T. Patterson, A.D. Gavrin, & W. Christian, *Just-in-Time Teaching: Blending Active Learning with Web Technology* (Prentice Hall, Upper Saddle River NJ, 1999).

Information on JiTT is available online at
http://webphysics.iupui.edu/jitt/jitt.html and
http://www.usafa.af.mil/dfp/research/cper/morejitt.htm.

Information on Physlets is available online at
http://webphysics.davidson.edu/Applets/Applets.html and
http://webphysics.davidson.edu/jitt/jitt_at_davidson.html

Related Readings:

G.M. Novak, E.T. Patterson, A. Gavrin, and R. C. Enger, "Just-in Time Teaching: Active Learners on the WWW," Paper presented at IASTED International Conference on Computers and Advanced Technology in Education , May 27 -30, 1998 in Cancun, Mexico. Available online at http://webphysics.iupui.edu/JITT/ccjitt.html.

S.W. Bonham, J.S. Risley and W. Christian, "Using Physlets to teach electrostatics," *The Physics Teacher* (submitted)

Peer Instruction

In Peer Instruction, short periods of lecture (12-20 minutes long) are broken up by multiple-choice questions that test students' conceptual understanding. The questions are designed to target student preconceptions and subtleties in the course material. After one minute, students record their individual responses and then try to convince their neighbors their answer is correct. After some time for animated discussion, students are allowed to reconsider their answer and respond again. Based on a poll of student responses, the instructor can go on to the next topic or spend more time on the current topic.

Materials:

E. Mazur, *Peer Instruction: A Users Manual* (Prentice Hall, New Jersey, 1997).

Related Readings:

D.E. Meltzer and K. Manivannan, "Promoting interactivity in physics lecture classes," *The Physics Teacher* **34**, 72-76 (1996).

E. Mazur, "Peer Instruction: Getting students to think in class," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 981-988.

Information is also available online at
http://mazur-www.harvard.edu/Education/EducationMenu.html.

SCALE-UP

The Student Centered Activities for Large Enrollment in University Physics (SCALE-UP) project is investigating methods for establishing a highly collaborative, hands-on, computer-intensive, interactive learning environment for large enrollment physics courses (class size from 50-100 students). The project involves the development, evaluation, and dissemination of research-based curricular materials to support active-learning activities in an integrated lecture/laboratory course as an economical alternative to traditional lecture-oriented courses. The curriculum materials are designed to be modular so that instructors can implement as few or as many of the SCALE-UP activities as befits their institution, resources, and teaching style.

Materials:

Information on the SCALE-UP project is available on the web at http://www2.ncsu.edu/ncsu/pams/physics/Physics_Ed/SCALE-UP%20Description.html. SCALE-UP curriculum materials will be available at this Web before the Spring 2000 semester/quarter.

Related Readings:

R. Beichner, L. Bernold, E. Burniston, P. Dail, R. Felder, J. Gastineau, M Gjestsen, and J. Risley, "Case study of the physics component of an integrated curriculum," *Physics Education Research: A Supplement to the American Journal of Physics* **67** (7), S16-S25 (1999).

Socratic Dialog Inducing Labs

Socratic Diologue Inducing labs are a series of active-learning laboratory experiments developed by Richard Hake at the University of Indiana. *SDI* Labs emphasize hands-on experience with simple mechanics experiments and facilitate students' active learning with course material. During the lab, the students work in groups through a series of questions that ask them to analyze and explain their observations. The questions are designed to elicit well-known student preconceptions and to provoke group discussions. Instructors ask questions in a Socratic fashion to guide students to a correct interpretation of their experiment by asking leading questions about conflicts between their preconceptions and what they observed.

Materials:

Curriculum materials are available from the University of Indiana's Research in Physics Education Group online at http://carini.physics.indiana.edu/SDI/phys-ed-new.html.

Related Readings:

R.R. Hake, "Socratic pedagogy in the introductory physics laboratory," *The Physics Teacher* **30**, 546-552 (1992). Available online at http://carini.physics.indiana.edu/SDI/.

R.R. Hake, "Promoting student crossover to the Newtonian world," *American Journal of Physics* **55**, 878-884 (1998).

Tutorials in Introductory Physics

These tutorials are concept-building activities in which groups of three to four students work collaboratively on specially designed worksheets. The worksheets guide students through the reasoning required to develop and apply important concepts and principles. Like the SDI labs, instructors use semi-Socratic questions to help students resolve conflicts between their preconceptions and the conflicts brought out by the worksheets. Many colleges and universities use tutorials as recitation or laboratory activities to supplement lecture instruction.

Materials:

L.C. McDermott and P.S. Shaffer, *Tutorials in Introductory Physics* (Preliminary edition) (Prentice Hall, Upper Saddle River NY, 1997).

Related Readings:

P.S. Shaffer and L.C. McDermott, "Research as a guide for curriculum development: An example from introductory electricity. Part II. Design of an instructional strategy," *American Journal of Physics* **60**, 1003-1013 (1992).

L.C. McDermott, P.S. Shaffer, and M.D. Somers, "Research as a guide for teaching introductory mechanics: An illustration in the context of the Atwood's machine," *American Journal of Physics* **62**, 46-55 (1994).

R.N. Steinberg, G.E. Oberem, and L.C. McDermott, "Development of a computer-based tutorial on the photoelectric effect," *American Journal of Physics* **64**, 1370-1379 (1996).

G.E. Francis, "Effectiveness of Tutorials in Introductory Physics," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 567-574.

L.C. McDermott, P.S. Shaffer, and S. Vokos, "Sample class on Tutorials in Introductory Physics," in *American Institute of Physics Conference Proceeding No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics Press, Woodbury NY, 1997), 1007-1018.

K. Wosilait, P.R.L. Heron, P.S. Shaffer, and L.C. McDermott, "Development and assessment of a research-based tutorial on light and shadow," *American Journal of Physics* **66**, 906-913 (1998).

K. Wosilait, P.R.L. Heron, P.S. Shaffer, and L.C. McDermott, "Addressing student difficulties in applying a wave model to the interference and diffraction of light," *Physics Education Research: A Supplement to the American Journal of Physics* **67** (7), S5-S15 (1999).

Useful References for a Conceptual Approach to Physics

P. Hewitt, *Conceptual Physics*, 8th ed. (Addison Wesley, New York, 1997).

L.C. McDermott, *Physics by Inquiry*, 2 Vols. (Wiley, New York NY, 1995).

Collaborative Learning

* D.W. Johnson, R.T. Johnson, and K.A. Smith, *ASHE-ERIC Higher Education Report 4—Cooperative Learning: Increasing College Faculty Instructional Productivity* (The George Washington University, Washington D.C., 1991).

D.W. Johnson, R.T. Johnson, and K.A. Smith, *Active Learning: Cooperation in the College Classroom*, 2nd Ed. (Interaction Book Co., Edina MN, 1998).

Richard Felder's website on innovative teaching and collaborative learning at North Carolina State University at http://www2.ncsu.edu/effective_teaching/.

Preconceptions and Student Learning

J. Clement, "Students' preconceptions in introductory mechanics," *American Journal of Physics* **50** (1), 66-71 (1982).

D.F. Dykstra, C.F. Boyle, and I.A. Monarch, "Studying conceptual change is learning physics," *Science Education* **76**, 615-652 (1992).

* I.A. Halloun and D. Hestenes, "Common sense concepts about motion," *American Journal of Physics* **53** (11), 1056-1065 (1985).

* L.C. McDermott, "Research on conceptual understanding in mechanics," *Physics Today* 37 (7), 24-32 (1984).

L.C. McDermott, M.L. Rosenquiest, and E.H. van Zee, " Student difficulties in connecting graphs and physics: Examples from kinematics," *American Journal of Physics* **55**, 503-513 (1987).

L.C. McDermott and P.S. Shaffer, ""Research as a guide for curriculum development: An example from introductory electricity. Part I. Investigation of student understanding," *American Journal of Physics* **60**, 1003-1013 (1992).

M.L. Rosenquist and L.C. McDermott, "A conceptual approach to teaching kinematics," *American Journal of Physics* **55**, 407-415 (1987).

R.K. Thornton, "Conceptual dynamics: Following changing student views of force and motion," in *American Institute of Physics Conference Proceedings No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics, Woodbury NY, 1997), 241-266.

Problem Solving

D.P. Maloney, "Research of problem solving: physics," in *Handbook of Research on Science Teaching and Learning*, edited by D.L. Gabel (Macmillan Publishing Company, New York, 1994), 327-354.

F. Reif and J.I. Heller, "Knowledge structure and problem solving in physics," *Educational Psychologist* **17**, 102-127 (1982).

R. Beichner, D. Deardorf, and B. Zhang, "GOAL-Oriented problem solving," submitted to Phys. Teach., (1998). Available online at http://www2.ncsu.edu/ncsu/pams/physics/Physics_Ed/Authors/Beichner.html.

Also see the two *American Journal of Physics* articles by Heller et. al listed above under Cooperative Group Problem Solving.

Cognitive Science and Expectations

I. Halloun, "Views about science and physics achievement: The VASS story," in *American Institute of Physics Conference Proceedings No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (American Institute of Physics, Woodbury NY, 1997), 605-614.

* D. Hammer, "Two approaches to learning physics," *The Physics Teacher* **27** (9), 664-670 (1989).

D. Hammer, "Epistemological beliefs in introductory physics," *Cognition and Instruction* **12**, 151-183 (1994). Available online at http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html.

D. Hammer, "Students' beliefs about conceptual knowledge in introductory physics," *Int. J Sci. Ed*. **16**, 385-403 (1994). Available online at http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html.

J. Mestre and J. Touger, "Cognitive research: what's in it for physics teachers," *The Physics Teacher* **27**, 447-456 (1989).

* E. F. Redish, "Implications of cognitive studies for teaching physics," *American Journal of Physics* **62** (9), 796-803 (1994). Available online at http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html.

E.F. Redish, J. M. Saul, and R.N. Steinberg, "Student expectations in physics," *American Journal of Physics* **66** (3), 212-224 (1998). Available online at http://www.physics.umd.edu/rgroups/ripe/perg/cpt.html.

Assessment & Evaluation Studies

R.J. Beichner, "Testing student interpretation of kinematics graphs," *American Journal of Physics* **62** (8), 750-762 (1994). Available online at R.R. Hake, "Active engagement vs. traditional methods: A six thousand student study of mechanics test data for introductory physics courses," *American Journal of Physics* 66 (1), 64-74 (1998). Available online at http://www.physics.umd.edu/rgroups/ripe/perg/perow.html.

I. Halloun, "Views about science and physics achievement: The VASS story," in *AIP Conference Proceedings No. 399 The Changing Role of Physics Departments in Modern Universities: Proceedings of the International Conference on Undergraduate Physics Education*, edited by E.F. Redish and J.S. Rigden (AIP, Woodbury NY, 1997), 605-614.

I.A. Halloun and D. Hestenes, "The initial knowledge state of students," *American Journal of Physics* **53** (11), 1043-1055 (1985).

* D. Hestenes, M. Wells, and G. Swackhamer, "Force Concept Inventory," *The Physics Teacher* **30** (3), 141-158 (1992).

D. Hestenes and M. Wells, "A mechanics baseline test," *The Physics Teacher* **30** (3), 159-166 (1992).

T. O'Brien Pride, S. Vokos, and L. C. McDermott, "The challenge of matching learning assessments to teaching goals: An example from the work-energy and impulse-momentum theorems," *American Journal of Physics* **66** (2), 147-152 (1998).

F. Reif and J.H. Larkin, "Cognition in scientific and everyday domains: Comparison and learning implications," *Journal of Research in Science Teaching* **28**, 733-760 (1991).

R.N. Steinberg and M.S. Sabella, "Performance on multiple-choice diagnostics and complementary exam problems," *The Physics Teacher* **35** (3), 150-155 (1997).

R.K. Thornton and D.R. Sokoloff, "Assessing student learning of Newton's laws: The Force and Motion Concept Evaluation and the evaluation of active learning laboratory and lecture," *American Journal of Physics* **66** (4), 338-351 (1998).

Additional Computer and Web Resources

WebAssign

WebAssign is a commercial homework database, delivery and grading system that allows instructors to assign multiple-choice, numeric, and essay problems over the web. Students submit responses over the web and in most cases receive immediate feedback to see if their answer is correct. This is a particularly useful resource for instructors who lack time for grading and graduate teaching assistants. Information on WebAssign can be found online at http://wwwassign.physics.ncsu.edu/. Additional information can be in A.P. Titus, L.W. Martin, and R.J. Beichner, "Web-based testing in physics education: Methods and opportunities," *Computers in Physics* **12** (2), 117-123 (1998) and L. Guernsey, "Textbooks and tests that talk back," *Chronicle of Higher Education*, Feb 12, 1999.

PIRA (the Physics Intructional Resource Association)
http://maxwell.phys.csufresno.edu:8001/pirapub/

PIRA exists to serve the needs of Physics Instructional Support Professionals through sharing ideas about demonstrations, laboratory activities, learning centers, and instructional resources in general. PIRA publishes a newsletter about every 2 months year-round with information about PIRA activities, tips to make demonstrations and labs more effective, and ideas for managing teaching centers, demonstration and laboratory facilities. Some current activities of PIRA include the demonstration classifcation scheme, a large demonstration design project, and a professional concerns committee. Reply to (rogerk@zimmer.scufresno.edu) for more information about the newsletter. [Note that suggested demonstrations in this manual are labeled using the PIRA classifications scheme.]

American Association of Physics Teachers
http://www.aapt.org/

APS Forum on Education
http://www.research.att.com/~kbl/APS/

Alan Cairn's Physics Education Resources
http://www.hpcc.astro.washington.edu/scied/physics.html

Physics Education E-mail Discussion Groups
http://www-hpcc.astro.washington.edu/scied/physics/physlists.html

The Internet Pilot TO Physics
http://physicsweb.org/TIPTOP/

Physics Education Research Articles Online
http://www.physics.umd.edu/rgroups/ripe/perg/perow.html

University of Maryland PER Group List of Physics Education Resources
http://www.physics.umd.edu/perg/ecs/phe.html

University of Massachussetts PER Group Outreach
http://WWW-PERG.PHAST.UMASS.EDU/outreach/default.html

University of Nebraska Research in Physics Education
http://www.physics.unl.edu/research/rpeg/rpeg.html