Appendix I.
Physics Education Resources

(compiled by Jose P. Mestre)

In this section we present a series of brief descriptions of recently developed materials for undergraduate physics. Each description was prepared by one of the authors of the materials. Each author also provided a series of written references and URLs for further information. The Task Force does not intend to endorse any of these resources over others that are not included in this appendix. These are the ones for which we received responses to a widely distributed solicitation within the physics community.

A. Physlets

Wolfgang Christian, Davidson College

The Physlet project is a synergy of curriculum development, computational physics, and physics education research. This project distributes a wide variety of class-tested interactive materials based on Java applets. Physlets employ a scripting language (JavaScript) to customize applets embedded within HTML pages, thereby allowing one applet to be used in many different contexts. This modular object-oriented software design enables Physlet adopters to easily author and customize their own interactive problems.

References

W. Christian and M. Belloni, *Physlets* (Prentice Hall, Upper Saddle River, NJ, 2001).

G. Novak , E. T. Patterson, A. Gavrin, and W. Christian, *Just In Time Teaching* (Prentice Hall, Upper Saddle River, NJ, 1999).

Website: *http://webphysics.davidson.edu/Applets/Applets.html*

B. Scale-Up

Robert Beichner, North Carolina State University

SCALE-UP stands for “Student-Centered Activities for Large Enrollment Undergraduate Programs.” We are adapting research-based pedagogies like collaborative, interactive learning so that they can be used in large-enrollment courses. This is done in a redesigned classroom environment of round tables and laptop computers where special classroom management techniques are utilized. Students are assigned to collaborative groups and spend most in-class time working on “tangible” (hands-on) and “ponderable” (“minds-on”) activities. The instructor and assistant(s) circulate and engage in Socratic dialogs with the students.

References

The precursor to SCALE-UP is described in R. Beichner, L. Bernold, E. Burniston, P. Dail, R. Felder, J. Gastineau, M. Gjertsen, and J. Risley, “Case study of the physics component of an integrated curriculum,” *Am. J. Phys.* (Phys. Ed. Res. Supplement) **67**, S16S24 (1999). *http://www.ncsu.edu/per/Articles/04IMPEC_AJP.pdf*

Also see:

Robert J. Beichner, Jeffrey M. Saul, Rhett J. Allain, Duane L. Deardorff, David S. Abbott, “Introduction to SCALE UP: Student-Centered Activities for Large Enrollment University Physics,” Proceedings of the 2000 Annual meeting of the American Society for Engineering Education (2000).

http://www.ncsu.edu/per/Articles/01ASEE_paper_S-UP.pdf

J. Saul, D. Deardorff, D. Abbott, R. Allain, and R. Beichner, "Evaluating introductory physics classes in light of ABET criteria: An Example of SCALE-UP Project," Proceedings of the 2000 Annual meeting of the American Society for Engineering Education (2000).
http://www.ncsu.edu/per/Articles/02ASEE2000_S-UP_Eval.pdf

R. Beichner, "Student-Centered Activities for Large Enrollment University Physics (SCALE-UP)," Proceedings of the Sigma Xi Forum "Reshaping Undergraduate Science and Engineering Education: Tools for Better Learning," Minneapolis, MN (2000).
ftp://ftp.ncsu.edu/pub/ncsu/beichner/RB/SigmaXi.pdf

Scale-Up Website*: http://www.ncsu.edu/per/scaleup.htm*

C. Workshop Physics

Priscilla Laws, Dickinson College

Workshop Physics is a calculus-based introductory curriculum designed to help students understand the basis of knowledge in physics through the interplay between observations, experiments, definitions, mathematical description, and the construction of theories. Instead of attending separate lecture and lab sessions, they attend three 2-hour-long sessions each week to predict, observe, experiment, and use a powerful set of computer tools to develop graphical and mathematical models of phenomena. The curriculum is embodied in a 28 Unit Activity Guide published by John Wiley & Sons.

References

P.W. Laws, "Calculus-Based Physics Without Lectures," *Physics Today* **44** (12), 24–31 (December 1991).

P.W. Laws, *Workshop Physics Activity Guide* (John Wiley & Sons, Inc., New York, NY, 1997).

P.W. Laws, "Millikan Lecture 1996: Promoting active learning based on physics education research in introductory physics courses," *Am. J. Phys*. **65,** 14–21 (1997).

P.W. Laws, "A New Order for Mechanics," Proceedings of the Conference on the Introductory Physics Course, P.W. Laws and J. Wilson, eds. (John Wiley & Sons, New York, NY, 1997), pp. 125–136.

J.M. Saul, "An Evaluation of the Workshop Physics Dissemination Project" (U. of Maryland, 1998).

Workshop Physics Website: *http://physics.dickinson.edu*

D. Investigative Science Learning Environment (ISLE)

Eugenia Etkina, Rutgers University

Alan Van Heuvelen, Ohio State University and Rutgers University

In ISLE students use the processes of science to construct and apply knowledge. They observe simple experiments, make qualitative explanations and develop quantitative laws, and devise experiments to test and, if needed, revise the laws. The laws and models are applied for useful purposes to real-world applications. These processes of science investigation are integrated with the results of research about learning—active student participation, multiple representations of processes, and multiple exposures to concepts.

References

E. Etkina and A. Van Heuvelen, "Investigative Science Learning Environment: Using the processes of science and cognitive strategies to learn physics," Proceedings of the 2001 Physics Education Research Conference, Rochester, NY, pp. 17–21 (2001).

Websites:

http://www-rci.rutgers.edu/%7Eetkina/isle.htm

http://www.pt3.gse.rutgers.edu/physics/frontp.html

E. ALPS and ActivPhysics (Active Learning in Large and Small Classes)

Alan Van Heuvelen, Ohio State University and Rutgers University

The *Active Learning Problem Sheets* (the *ALPS Kits*) are paper-and-pencil activities that help students participate in learning in lectures and recitations. The kits include qualitative questions, multiple-representation activities, and problems done in a multiple-representation format. *ActivPhysics* is a comprehensive multimedia product that has similar activities as in the ALPS Kits with the added advantage of providing simultaneous simulated processes and dynamic representations of these processes.

References

Alan Van Heuvelen, "Millikan Lecture: The Workplace, Student Minds, and Physics Learning Systems," *Am. J. Phys.* **69,** 1139–1146 (2001).

Alan Van Heuvelen, Active Learning Problem Sheets: Mechanics and Electricity and Magnetism (Hadyn-McNeil, Plymouth, MI,1990).

Alan Van Heuvelen and P. D'Alessandris, *ActivePhysics I and II* (Addison-Wesley-Longman, Palo Alto, CA, 1998).

F. Matter and Interactions, Electric and Magnetic Fields

Bruce Sherwood and Ruth Chabay, North Carolina State University

The two-volume introductory calculus-based college physics textbook *Matter & Interactions* by Ruth Chabay and Bruce Sherwood (Wiley 2002) emphasizes the atomic nature of matter with macro-micro connections and engages students in modeling complex phenomena, including computer modeling. Analyses start from a small number of fundamental principles. Mechanics and thermal physics are treated as a single unified subject, as are electrostatics and circuits. The intent is to make introductory physics reflect the contemporary physics enterprise.

References

R.W. Chabay and B.A. Sherwood, "Bringing atoms into first-year physics," *Am. J. Phys.* **67,** 1045–1050 (1999).

http://www.wiley.com/college/chabay for the textbook, with a link from there to our own public website with additional materials, including free educational software. See *http://vpython.org* for the 3D programming environment developed for use with our curriculum.

G. Teaching Physics Through Cooperative Group Problem Solving

Ken Heller and Patricia Heller, University of Minnesota

Students solve Context-Rich quantitative problems that emphasize making expert-like decisions based on physics concepts. Student support includes teaching a general problem-solving framework and coaching using cooperative groups. This approach follows the Cognitive Apprenticeship paradigm of modeling, coaching, and fading. The modeling of desired problem-solving behavior is in lectures and in written problem solutions while coaching occurs in discussion sections and laboratories where the students work Context-Rich problems in cooperative groups.

References

P. Heller, R. Keith, and S. Anderson, "Teaching problem solving through cooperative grouping. Part 1: Groups versus individual problem solving," *Am. J. Phys.* **60,** 627–636 (1992).

P. Heller and M. Hollbaugh, "Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups," *Am. J. Phys.* **60,** 637–645 (1992).

P. Heller, T. Foster, and K. Heller, "Cooperative group problem solving laboratories for introductory classes," in E. F. Redish and J. S. Rigden, eds. *The Changing Role of Physics Departments in Modern Universities: Proceedings of International Conference on Undergraduate Physics Education* (American Institute of Physics, Woodbury, NY, 1996).

Website: *http://www.physics.umn.edu/groups/physed/*

H. Peer Instruction

Eric Mazur and Catherine Crouch, Harvard University

Peer Instruction engages students in class by asking questions that require each student to apply the core concepts being presented, and then to explain those concepts to their fellow students. Class consists of short lecture segments interspersed with a related conceptual question, called a ConcepTest, which probes students' understanding of the ideas just presented. Students formulate individual answers, then discuss their answers with others sitting around them for two to four minutes. Finally, the instructor calls an end to the discussion, explains the answer, and moves on to the next topic.

References

Catherine H. Crouch and Eric Mazur, "Peer Instruction: Ten Years of Experience and Results," *Am. J. Phys.* **69,** 970–977 (2001).

Adam P. Fagen, Catherine H. Crouch, and Eric Mazur, "Peer Instruction: Results from a Range of Classrooms," *Phys. Teach.* **40,** 206–209 (2002).

Eric Mazur, *Peer Instruction: A User's Manual* (Prentice Hall, Upper Saddle River, NJ, 1997).
Website: *http://galileo.harvard.edu/lgm/pi* (Note that this website requires free registration, so on your first visit, you get bounced to a login page which provides links to a registration area).

I. Just-in-Time Teaching (JiTT)

Evelyn Patterson, Air Force Academy

Just-in-Time Teaching (JiTT) is a teaching and learning strategy that exploits interaction between web-based study and an active learner classroom. Students respond electronically to carefully constructed web-based assignments due shortly before class, and the instructor reads the student submissions "just-in-time" to adjust the lesson to suit the students' needs. The heart of JiTT is the "feedback loop" formed by the students' outside-of-class preparation that fundamentally affects what happens during the subsequent in-class time together.

References

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

Webreport: *http://www.pkal.org/pubs/Rothman.pdf*

"Then, Now, and in the Next Decade: A Commentary on Strengthening Undergraduate Science, Math, Engineering and Technology Education" publication which features JiTT on p. 18.

Webreport: *http://a-s.clayton.edu/henry/JiTT.htm*

Gregor Novak and Joan Middendorf, "Just-in-Time Teaching: Using Web Technology To Increase Student Learning," ISETA *Connexions* Newsletter **14** (1), (Spring 2002).

http://webphysics.iupui.edu/JiTT/CATE2000.doc

Gregor Novak and Evelyn Patterson, "The Best of Both Worlds: WWW Enhanced In-Class Instruction," in the Proceedings of the IASTED "Computers and Advanced Technology in Education" [CATE] 2000 International Conference, May 24–27, 2000.

JiTT website: *http://www.jitt.org or http://webphysics.iupui.edu/jitt/jitt.html*

J. Tutorials in Introductory Physics

Lillian McDermott, University of Washington

The Physics Department at the University of Washington has implemented a system of tutorials throughout the introductory calculus-based course. Beginning in 1991 with one lecture section in the mechanics portion of the course, weekly tutorials subsequently became an integral part of the entire first-year sequence, including the honors section. The instructional materials that are used in the 50-minute small sections have been published in *Tutorials in Introductory Physics.* The development of the tutorials has been guided by ongoing research on the learning and teaching of physics and includes continuous assessment through pretests and post-tests. Rigorous T.A. preparation and examinations that include questions on the content in the tutorials are essential for effective adoption. Although there is no direct evidence that the tutorials or the associated T.A. preparation are responsible, their inclusion in the department's instructional program correlates with a rise in the number of graduating physics majors to more than 50 in 2002.

The tutorials comprise an integrated system of pre-tests, worksheets, homework assignments, and post-tests. The tutorial sequence begins with a pre-test that helps students identify what they do and not understand about the material and what they are expected to learn in the upcoming tutorial. The pre-tests also inform the instructors about the level of student understanding. The worksheets, which consist of carefully sequenced tasks and questions, provide the structure for the tutorial sessions. Students work together in small groups, constructing answers for themselves through discussions with one another and with the tutorial instructors. The tutorial instructors do not lecture but ask questions designed to help students find their own answers. The tutorial homework reinforces and extends what is covered in the worksheets.

Post-test results, published in a number of articles, show a significant improvement in student understanding as a result of the tutorials. Furthermore, there has been no decrease in the ability of students to solve standard quantitative problems even though less time is spent in practice on problem solving. Results from pilot sites, ranging from two-year colleges to research universities, demonstrate that the tutorials work equally well in calculus-based and algebra-based courses.

Supported in part by the National Science Foundation, the development of Tutorials in Introductory Physics has been a collaborative effort by all members of the Physics Education Group at the University of Washington, past and present, with contributions by colleagues at other institutions. Leadership in the ongoing development of the tutorials is provided by Lillian C. McDermott, Peter S. Shaffer, and Paula R. L. Heron.

References

Lillian C. McDermott, Peter S. Shaffer, and the Physics Education Group at the University of Washington, *Tutorials in Introductory Physics* (Prentice Hall, Upper Saddle River, NY, Preliminary Edition 1998, First Edition 2002, and Instructor's Guide 2003).

For articles that discuss the motivation for the tutorials and provide an overall description, see:

L.C. McDermott, Millikan Award 1990, "What we teach and what is learned: Closing the gap," *Am. J. Phys.* **59** (4) 301 (1991).

L.C. McDermott, Guest Comment: "How we teach and how students learn—A mismatch?" *Am. J. Phys.* **61** (4) 295 (1993).

L.C. McDermott, Response for the 2001 Oersted Medal, "Physics education research: The key to student learning," *Am. J. Phys.* **69** (11) 1127–1137 (2001).

For articles that illustrate the research that guided the tutorials and describe some specific instructional strategies, see, for example:

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," *Am. J. Phys.* **60** (11) 994 (1992); "Part II: Design of instructional strategies," *ibid*. **60** (11) 1003 (1992); Printer's erratum to Part I, *ibid.* **61** (81) (1993).

B.S. Ambrose, P.S. Shaffer, R.N. Steinberg, and L.C. McDermott, "An investigation of student understanding of single-slit diffraction and double-slit interference," *Am. J. Phys*. **67** (2) 146 (1999).

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," *Am. J. (Phys. Ed. Res. Supplement)* **67** (7) S5 (1999).

The group's URL is *http://www.phys.washington.edu/groups/peg/*.

K. Classroom Communication Systems: Transforming Large Passive Lecture Classes into Interactive Learning Environments

Bill Gerace and Jose Mestre, University of Massachusetts–Amherst

How does one provide a pedagogically sound experience for students enrolled in introductory science classes at large universities, which are commonly taught in large lecture formats numbering from 100–400 students? An emerging technology, classroom communication systems (CCSs), has the potential to transform the way we teach science in large lecture settings. CCSs can serve as catalysts for creating a more interactive, student-centered classroom in the lecture hall, thereby allowing students to become more actively involved in constructing and using knowledge. CCSs not only make it easier to engage students in learning activities during lecture but also enhance the communication among students, and between the students and the instructor. This enhanced communication assists the students and the instructor in assessing understanding during class time, and affords the instructor the opportunity to devise instructional interventions that target students' needs as they arise. In short, CCSs greatly facilitate the instructor's ability to provide an active learning experience for students, to provide feedback to students on their learning, to accommodate different learning styles, to make students' thinking visible, and to provide instruction tailored to students' learning needs—all desirable instructional strategies based on learning principles described in a new report from the National Research Council titled *How People Learn: Brain, Mind, Experience and School.*

Classtalk and Personal Response System (PRS) are two CCSs being used extensively at UMass–Amherst. They are both a combination of software and hardware that permit the presentation of questions for small-group consideration, as well as the collection of answers and the class-wide display of a histogram of student answers. The display of the histogram is the springboard for a class-wide discussion of the ideas and methods used to analyze situations and solve problems. The time devoted to lecturing is decreased, while the time students devote to developing and refining their conceptual understanding is increased. The instructor's role, therefore, more closely resembles that of a coach than a dispenser of information.

CCSs are a tool, and by themselves do not contain any pedagogical components. The development of sound pedagogical strategies for using CCSs has been the focus of the Physics Education Research Group (PERG) at UMass–Amherst since 1993. UMass PER researchers have published articles on effective uses of CCSs in teaching introductory science (see below). In addition, PER members have conducted numerous workshops with UMass faculty to help them make the transition from student-passive, lecture-style instruction, to student-active, CCS-based instruction. Currently PER continues to provide ongoing technical and pedagogical support to instructors using CCSs in the Physics and Biology departments.

Thus far, 10 introductory courses across four departments at UMass (two courses in Sociology, one in economics, two in biology, and six in physics) have used CCS's to teach large introductory courses. In all cases, both instructors and students have had a very positive experience.

References

R.J Dufresne, W.J. Gerace, W.J. Leonard, J.P. Mestre, and L. Wenk, "Classtalk: A classroom communication system for active learning" *J. of Computing in Higher Educ.* **7,** 3–47 (1996).

J.P. Mestre, W.J. Gerace, R.J. Dufresne, and W.J. Leonard, "Promoting active learning in large classes using a classroom communication system," in E.F. Redish and J.S. Rigden, eds., *The Changing Role of Physics Departments in Modern Universities: Proceedings of International Conference on Undergraduate Physics Education* (American Institute of Physics, Woodbury, NY, 1997), pp. 1019–1036.

L. Wenk, R. Dufresne, W. Gerace, W. Leonard, and J. Mestre, "Technology-assisted active learning in large lectures," in C. D'Avanzo and A. McNichols, eds., *Student-active Science: Models of Innovation in College Science Teaching* (Saunders College Publishing, Philadelphia, PA, 1997), pp.431–452.

Website: *http://umperg.physics.umass.edu/*

L. Video Analysis in the Physics Laboratory

Dean Zollman, Kansas State University

Over the past 15 years video has become a common tool for analysis in the physics laboratory. When students collect data from an event recorded on video, they are using real events to help them understand how the motions are visualized. Interactive video aids students in understanding a variety of complex situations by enabling them to manipulate and measure variables. Data collection can be partially automated while nonlinear video provides flexibility in interactivity. Newer uses of video combined with simulation and modeling tools help students create visual but abstract models of physical processes. These methods provide new pedagogical tools for physics students and offer a much broader learning opportunities.

References

Dean Zollman and Robert Fuller, "Teaching and learning physics with interactive video," *Physics Today* **47** (4), 41–47 (1994).

Lawrence Escalada, Dean Zollman, and Robert Grabhorn, "Applications of interactive digital video in a physics classroom," *J. of Educ. Multimedia and Hypermedia* **5,** 73-97 (1996).

Lawrence T. Escalada and Dean Zollman, "An investigation on the effects of using interactive video in a physics classroom on student learning and attitudes," *J. of Res. in Science Teaching* **34**, 476–489 (1996).

Dean Zollman, "Millikan Lecture 1995: Do they just sit there? Reflections on helping students learn physics," *Am. J. Phys*. **64**, 114–119 (1996).

Teresa Larkin-Hein and Dean Zollman, "Digital video, learning styles, and student understanding of kinematics graphs," *J. of SMET Educ.* **1/1**, 4–17 (2000).

Priscilla Laws and Hans Pfister, "Using digital video analysis in introductory mechanics projects," *Phys. Teach.* **36,** 282–287 (1998).

Dean Zollman "Physics" in *Handbook on Information Technologies for Education and Training*, H.H. Adelsberger, B. Collis, and J.M. Pawlowski, eds. (Springer-Verlag, Berlin, 2002), pp 459–470. Kansas State University Physics Education Research Group: *http://www.phys.ksu.edu/perg/*

Vidshell 2000 (Doyle Davis), *http://webphysics.tec.nh.us/vidshell/clips.html*

VideoPoint, *http://www.lsw.com/videopoint/*

World in Motion, *http://members.aol.com/raacc/wim.html*
DAVID–Digitale Auswertung von Videos (in German)
http://www.physik.uni-muenchen.de/didaktik/Computer/DAVID/david.htm
Interactive Screen Experiments (in English & German), *http://bifrost.physik.tu-berlin.de/ibe/index.html*

M. Introductory Physics at a Large Research University

Gary Gladding, University of Illinois at Urbana–Champaign

The introductory physics courses at the University of Illinois at Urbana–Champaign have been completely revised in the last five years. The thrust of the revision was to integrate all aspects of a course using active-learning methods based on physics education research in a team-teaching environment.

References

The revisions are documented at:
http://www.physics.uiuc.edu/Education/Course_Revision.html.

A paper describing the project can be found at:
http://www.physics.uiuc.edu/Education/Course_Revision.html

N. RealTime Physics

David Sokoloff, University of Oregon and Ron Thornton, Tufts University

RealTime Physics (RTP) is an introductory laboratory curriculum for those desiring a complete, sequenced set of active learning laboratory activities for an entire semester or quarter, without changing the traditional course structure of lectures and labs. RTP is based on physics education research, makes use of a learning cycle of predictions, observations, comparison and conclusions, and focuses on conceptual and quantitative understanding. Microcomputer-based tools are used extensively, and computers are also used for modeling, data analysis, and simulations. The activities are written generically—using Experiment Configuration Files—so that they are not dependent on a particular hardware and software package. Module 1: Mechanics, Module 2: Heat and Thermodynamics and Module 3: Electric Circuits are published by Wiley. Light and Optics is under development.

References

Ronald K. Thornton and David R. Sokoloff, "RealTime Physics: Active Learning Laboratory," in E.F. Redish and J. R. Rigden, eds., *The Changing Role of the Physics Department in Modern Universities, Proceedings of the International Conference on Undergraduate Physics Education* (American Institute of Physics, Woodbury, NY, 1997), pp. 1101–1118.

Ronald K. Thornton and David R. Sokoloff, "Assessing student learning of Newton's laws: The force and motion conceptual evaluation and the evaluation of active learning laboratory and lecture curricula," *Am. J. Phys.* **66,** 338–352 (1998).

http://ase.tufts.edu/csmthttp://wiley.com/college/sokoloff-physics

O. Interactive Lecture Demonstrations

David Sokoloff, University of Oregon and Ron Thornton, Tufts University

Interactive Lecture Demonstrations (ILDs) are designed to enhance conceptual learning in large (and small) lectures. They are also useful in classrooms where only one computer is available. ILDs are based on physics education research, make use of a learning cycle of predictions, observations, comparison and conclusions, focus on conceptual understanding, and most make use of microcomputer-based laboratory (MBL) tools. The ILD procedure involves students recording individual predictions of the outcomes of simple experiments on a Prediction Sheet (which is collected), discussing their predictions with neighbors and then comparing their predictions to the actual results displayed for the class with the MBL tools. Interactive Lecture Demonstrations in Motion, Force and Energy are available from Vernier Software and Technology. ILDs in other areas are under development.

References

David R. Sokoloff and Ronald K. Thornton, "Using interactive lecture demonstrations to create an active learning environment," *Phys. Teach.* **35** (6), 340 (1997).

Ronald K. Thornton and David R. Sokoloff, "Assessing student learning of Newton's laws: The force and motion conceptual evaluation and the evaluation of active learning laboratory and lecture curricula," *Am. J. Phys.* **66,** 338–352 (1998).

Websites: *http://ase.tufts.edu/csmt and http://www.vernier.com/cmat/ild.html*

P. Studio Physics

Karen Cummings, Southern Connecticut State University

"Studio" teaching is a pedagogical approach rather than a specific curriculum. Developed and refined at Rensselaer between 1995 and 2002, the Studio approach integrates lectures, hands-on activities and instruction in problem solving in each class meeting. A premium is placed on student interactions within groups and with research-active professors. Extensive use of technology helps to make this approach effective in producing student learning and manageable for use at research universities.

References

For more information, see the references below or contact Karen Cummings at karen@rpi.edu or Jack M Wilson at JackMWilson@JackMWilson.com .

J. Wilson, "The CUPLE physics studio," *Phys. Teach.* **32** (9), 518–523 (1994).

K. Cummings and J. Marx, "Evaluating innovations in studio physics," *Am. J. Phys*. (*Phys. Ed. Res. Supplement*) **67** (7), S38-S44 (1999).

Q. Other Web Resources

Here we mention a few websites that offer collections of information on undergraduate physics and links to many other undergraduate physics web resources:

- The American Association of Physics Teachers maintains a website "Physical Sciences Resource Center," which contains much information and many links to other sources about undergraduate physics. *http://www.aapt.org*
- Project Galileo at Harvard University contains a collection of resources for undergraduate physics. *http://galileo.harvard.edu/lgm/pi*
- The large-scale digital library project comPADRE for physics is under development as of this writing (early 2003). Preliminary materials are expected to be ready through the AAPT website during the fall of 2003.

Appendix II. Undergraduate Physics Reading List

(compiled by J. D. Garcia)

NTFUP's goals include encouraging awareness of the changing educational environment, promoting best practices in undergraduate physics education and providing mechanisms for greater dialog among physicists concerning undergraduate physics education. As a means of encouraging discussion and as a starting point for thinking about what has worked at various places, we have assembled an admittedly incomplete and selective set of articles and materials from the literature dealing with the teaching of physics and with physics education research. The resource letter on physics education research [McDermott and Redish, 1999] is a much larger bibliography on literature on the subject.

We encourage you to read this material and discuss it with your colleagues. These readings are intended to be only a starting point for discussions. Indeed, were we to include material on all programs, practices, and innovations that we deem worthwhile, the list would be prohibitively long.

Patricia Heller, Ronald Keith, and Scott Anderson, "Teaching problem solving through cooperative grouping. Part 1: Group vs. individual problem solving," *Am. J. Phys.* **60,** 627 (1992).

Patricia Heller, Ronald Keith, and Scott Anderson, "Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups," *Am. J. Phys.* **60,** 637 (1992).

William J. Leonard, Robert J. Dufresne, and Jose P. Mestre, "Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems," *Am J. Phys.* **64,** 1495 (1996).

Robert C. Hilborn, "Guest Comment: Revitalizing undergraduate physics—Who needs it?" *Am. J. Phys.* **65,** 175 (1997).

Edward F. Redish, "Millikan Lecture 1998: Building a science of teaching physics," *Am. J. Phys.* **67,** 562 (1997).

Eric Mazur, *Peer Instruction,* Chapter 2: Concepttests, (Prentice Hall, Upper Saddle River, NJ, 1997).

Lillian McDermott, "Bridging the Gap Between Teaching and Learning: the Role of Research," in *Proceedings of the International Conference on Undergraduate Physics Education,* CP399, edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 139–165.

Frederick Reif, "How Can We Help Students Acquire Effectively Usable Physics Knowledge?" in *Proceedings of the International Conference on Undergraduate Physics Education*, CP399, edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 179–195.

Rosanne Di Stefano, "Where an Instructor's Dreams Meet Reality: Total Available Student Time," in *Proceedings of the International Conference on Undergraduate Physics Education, CP399,* edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 225–239.

Ronald K. Thornton, "Conceptual Dynamics: Following Changing Student Views of Force and Motion," in *Proceedings of the International Conference on Undergraduate Physics Education,* CP399, edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 241–265.

Richard R. Hake, "Evaluating Conceptual Gains in Mechanics: A Six Thousand Student Survey of Test Data," in *Proceedings of the International Conference on Undergraduate Physics Education,* CP399, edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 595–603.

Fred Goldberg, "How Can Computer Technology be Used to Promote Learning and Communication Among Physics Teachers?" in *Proceedings of the International Conference on Undergraduate Physics Education,* CP399, edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 2375–2392.

Richard Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys*. **66**, 64–74 (1998).

Lillian C. McDermott and Edward F. Redish, "Resource Letter: PER 1: Physics education research," *Am. J. Phys.* **67,** 755–767 (1999).

Ruth H. Howes and Robert C. Hilborn, "Guest Comment: Winds of change," *Am. J. Phys.* **68,** 40 (2000).

Corinne A. Manogue, Philip J. Siemens, Janet Tate, Kerry Browne, Margaret Niess, and Adam J. Wolfer, "Paradigms in physics: A new upper-division curriculum," *Am. J. Phys.* **69,** 978 (2001).

Edward F. Redish, *Teaching Physics* (John Wiley & Sons, New York, 2003).

Appendix III.
Presentations and Articles on SPIN-UP

A. Presentations

1. APS Meeting, Long Beach, CA, April 2000.

What's Happening in Undergraduate Physics Revitalization?
Robert C. Hilborn (University of Nebraska-Lincoln)

The American Association of Physics Teachers, the American Physical Society, and the American Institute of Physics have recently launched the National Task Force on Undergraduate Physics. The Task Force's initial activities are also supported by a planning grant from the Exxon Education Foundation. The goal of the Task Force is to coordinate a number of activities led by AAPT, APS, AIP and others to foster the "revitalization" of undergraduate physics programs across the country. The Task Force will also provide advice about new activities aimed at undergraduate physics. This effort emphasizes all aspects of undergraduate physics including the recruitment and mentoring of students, providing strong courses for physics majors, other science majors, nonscience majors and pre-service K–12 teachers, engaging students in research, and preparing students for a diverse set of careers. The Task Force focuses on the department as the fundamental unit for undergraduate education change while recognizing that innovations must be adapted to suit local needs. In this talk I will give some background of the events leading up to the establishment of the Task Force. I will also discuss some of the activities aimed at revitalizing undergraduate physics and plans for future programs under discussion by the Task Force.

2. AAPT Meeting, Guelph, Ontario August 1, 2000.

What's Happening in Undergraduate Physics Revitalization?
Robert C. Hilborn (Amherst College)

AAPT, the American Physical Society (APS), and the American Institute of Physics (AIP) have recently launched the National Task Force on Undergraduate Physics. The Task Force's initial activities are also supported by a planning grant from the ExxonMobil Foundation. The goal of the Task Force is to coordinate a number of activities led by AAPT, APS, AIP, and others to foster the "revitalization" of undergraduate physics programs across the country. The Task Force will also provide advice about new activities aimed at undergraduate physics. This effort emphasizes all aspects of undergraduate physics including: recruiting and mentoring students; providing strong courses for physics majors, other science majors, nonscience majors, and pre-service K–12 teachers; engaging students in research; and preparing students for a diverse set of careers. The Task Force focuses on the department as the fundamental unit for undergraduate education change while recognizing that innovations must be adapted to suit local needs. In this talk I will give some background of the events leading up to the establishment of the Task Force. I will also discuss some of the activities aimed at revitalizing undergraduate physics and plans for future programs under discussion by the Task Force.

3. APS Meeting, Washington, DC, April, 2001.

Building Undergraduate Physics Programs for the 21st Century
Robert C. Hilborn (Amherst College)

Undergraduate physics programs in the United States are under stress because of changes in the scientific and educational environment in which they operate. The number of undergraduate physics majors is declining nationwide; there is some evidence that the "best" undergraduate students are choosing majors other than physics, and funding agencies seem to be emphasizing K–12 education. How can physics departments respond creatively and constructively to these changes? After describing some of the details of the current environment, I will discuss the activities of the National Task Force on Undergraduate Physics, supported by the American Institute of Physics, the America Physical Society, the American Association of Physics Teachers and the ExxonMobil Foundation. I will also present some analysis of Task Force site visits to departments that have thriving undergraduate physics programs, pointing out the key features that seem to be necessary for success. Among these features are department-wide recruitment and retention efforts that are the theme of this session.

4. PKAL Summer Institute, Williamsburg, VA, June 2–5, 2002.

Brief presentation to all participants by Robert C. Hilborn (Amherst College).

5. AAPT/APS Physics Department Chairs Meeting, College Park, MD, June, 2002.

Report on Site Visits to Physics Departments
Ruth H. Howes (Ball State University)

6. NSF Physics, MPS, and DUE program officers, Arlington, VA, June 13, 2002.

Summary of SPIN-UP results presented by Robert C. Hilborn (Amherst College).

7. AAPT 2002 Summer Meeting, Boise, ID, August 5, 2002.

The National Task Force on Undergraduate Physics and SPIN-UP
Robert C. Hilborn (Amherst College)

The National Task Force on Undergraduate Physics, a joint effort of the American Association of Physics Teachers, the American Physical Society, the American Institute of Physics, and Project Kaleidoscope, was established in 1999 to provide advice to the physics professional societies and the physics community at large about the state of undergraduate physics. After reviewing some of the background leading up to the establishment of the Task Force, I will describe the project Strategic Programs for Innovations in Undergraduate Physics (SPIN-UP), a Task Force effort funded by the ExxonMobil Foundation. SPIN-UP focuses on site visits to about 20 colleges and universities that have thriving undergraduate physics programs and a survey, conducted in cooperation with AIP, of all undergraduate physics departments in the country. I will discuss the common features, identified from the site visits, found in departments that have thriving undergraduate physics programs.

The SPIN-UP Survey of Undergraduate Physics Programs
Kenneth Krane (Oregon State University)

In spring 2002, SPIN-UP (Strategic Programs for Innovations in Undergraduate Physics) of the National Task Force on Undergraduate Physics conducted (through the American Institute of Physics) a survey of undergraduate physics programs throughout the United States. Among the information that the survey form was designed to elicit were: (1) undergraduate curricula, including the character of the department's "standard" degree track and any alternative degree tracks that are available; (2) activities for recruiting undergraduate majors; (3) interactions between faculty and physics majors, including advising and mentoring as well as informal contacts; (4) alumni relations; and (5) curricular reform efforts. In addition to gathering information, the survey asked departments to evaluate the success of these activities and to discuss the current strengths and needs of the department. We will review the survey document and present the results analyzed to date.

Using the Results: Next Steps and Getting Involved
Ruth Howes (Ball State University)

SPIN-UP (Strategic Programs for Innovations in Undergraduate Physics) has studied the condition of undergraduate physics programs in all kinds of colleges and universities through site visits and a survey, the results of which have been presented in this session. We have focused on thriving departments with successful undergraduate programs. Not all undergraduate physics programs are thriving. The National Task Force on Undergraduate Physics is preparing to use the results of SPIN-UP to help other departments change constructively. We report on future plans and opportunities for AAPT members to become involved in improving undergraduate physics programs.

8. European Union Physics Departments Meeting, Varna, Bulgaria, September 7, 2002.

Presentation by Ruth H. Howes (Ball State University)

9. NSF-Corporate Foundation Alliance Meeting, Arlington, VA, October 23, 2002.

Presentation by Robert C. Hilborn (Amherst College).

10. Mid-West Physics Department Chairs Meeting, Chicago, November 3, 2002.

SPIN-UP Results and Analysis
Robert C. Hilborn (Amherst College)

B. Articles about the Task Force, and SPIN-UP and Related Activities.

"Revitalizing physics education," *Physics Today* **53** (4), 59–60 (April 2000). Brief notice about the formation of the Task Force.

"APS, AIP, and AAPT launch task force on undergrad physics," *APS News* **9** (4) (April 2000).

"The physics department 'Cosmo Quiz'," *APS News* **9** (4) (April 2000).

D. E. Neuenschwander, "What does 'Physics Revitalization" mean?" *Reveille* 2000.

Ruth H. Howes and Robert C. Hilborn, "Winds of change," *Am. J. Phys*. **68,** 401–402 (2000).

Robert C. Hilborn, "The National Task Force on Undergraduate Physics: Some FAQs," *APS Forum on Education Newsletter* (Spring/Summer 2000).

Carl Wieman, "A Modest proposal: Recruit undergraduate majors," *APS News* **10** (5) (May 2001).

Robert C. Hilborn, "The National Task Force on Undergraduate Physics," National Research Council Board on Physics and Astronomy *BPA News* (June 2001).

"Amherst Professor Hilborn to head National Task Force on Undergraduate Physics," *Amherst College Notes*, August 30, 2001.

"SPIN-UP seeks undergraduate programs to host site visits," *APS News* **12** (12) (December 2001).

Ken Krane, "What produces a thriving undergraduate physics program?" *APS News* 11 (11) (November, 2002).