S
ince publication of the AAAS 1989 re-
port “Science for all Americans” (1),
commissions, panels, and working
groups have agreed that reform in science
education should be founded on “scientific
teaching,” in which teaching is approached
with the same rigor as science at its best (2).
Scientific teaching involves active learning
strategies to engage students in the process
of science and teaching methods that have
been systematically tested and shown to
reach diverse students (3).

Given the widespread agreement, it may
seem surprising that change has not pro-
gressed rapidly nor been driven by the re-
search universities as a collective force.
Instead, reform has been initiated by a few pi-
oneers, while many other scientists have ac-
tively resisted changing their teaching. So
why do outstanding scientists who demand
rigorous proof for scientific assertions in
their research continue to use and, indeed,
defend on the basis of the intuition alone, teach-
ning methods that are not the most effective?
Many scientists are still unaware of the data
and analyses that demonstrate the effective-
ness of active learning techniques. Others
may distrust the data because they see scien-
tists of all disciplines have developed
inexpensive materials con-
figured so that they invite students to ask
write about their results (3).

Some scientists have replaced lectures al-
most entirely. Law’s course “Calculus-Based
Physics Without Lectures” at Dickinson Uni-
certainty (5) and Becker’s program,
SCALE-UP, at North Carolina State Uni-
versity (see figure, this page) rely on a prob-
lem-based format in which students work col-
laboratively to make observations and to ana-
lyze experimental results. Students who
learned physics in the SCALE-UP format at a
wide range of institutions demonstrated better
problem-solving ability, conceptual under-
standing, and success in subsequent courses
compared with students who had learned in
traditional, passive formats (3).

These results are neither isolated nor
discipline-specific. At the University of
Oregon, Udovic showed dramatic differ-
ces between students taught biology in a
traditional lecture and those taught “Work-
shop Biology,” a series of active, inquiry-
Based learning modules (6). Similarly im-
pressive results were achieved by Wright in a
comparison of active and passive learning
strategies in chemistry (7). Others have
taught cross-disciplinary problem-based
courses that integrate across scientific dis-
ciplines, such as Trempey’s, “The World
According to Microbes,” at Oregon State University,
which integrates science, math, and engineering. The
course serves science ma-

A physics classroom at North Carolina State
University arranged for traditional lectures (inset)
and redesigned for group problem-solving
in the SCALE-UP program.

Faculty are also using computer sys-
tems to engage students, assess learning,
and shape teaching. Students can be asked
to read and solve problems on a Web site,
and their answers can be analyzed before
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According to Microbes,” at Oregon State University,
which integrates science, math, and engineering. The
course serves science ma-
al classroom lab course (3). These opportunities are challenging for instructors, but teach students the essence of investigation.

**How Universities Can Promote Change**

Research universities should provide leadership in the reform movement. Faculty and administrators should collaborate to overcome the barriers and to create an educational ethos that enables change. We need to inform scientists about education research and the instructional resources available to them so that they can make informed choices. We must admit that citing our most successful students as evidence that our teaching methods are effective is simply not scientific. Instead, we need to apply innovative metrics to assess the outcomes of teaching. Controlled experiments and meta-analyses that compare student achievement with various teaching strategies provide a compelling basis for pedagogical choices (4), but the need for assessment extends into every classroom. Many tools to assess learning are available (5). Assessments of long-term retention of knowledge, entrance into graduate school, and employment and professional success should be included as well.

Research universities should overhaul introductory science courses for both science majors and nonmajors using the principles of scientific teaching. The vision should originate from departments and be supported by deans and other academic administrators. Science departments should incorporate education about teaching and learning into graduate training programs and should integrate these initiatives into the educational environment and degree requirements. This could include, for example, development of peer-reviewed instructional materials based on the student’s thesis research. Funding agencies have a responsibility to promote this strategy. National Institutes of Health and the National Science Foundation should, for example, require that graduate students supported on training grants acquire training in teaching methods, just as the NIH has required training in ethics.

Universities need to provide venues for experienced instructors to share best practices and effective teaching strategies. This will be facilitated, in part, by forming educational research groups within science departments. These groups might be nucleated by hiring tenure-track faculty who specialize in education, as 47 physics departments have done in the past 6 years. Other strategies include incorporating sessions about teaching into their seminar series, developing parallel series about teaching, or establishing instructional material “incubators” where researchers incorporate research results into teaching materials with guidance from experts in pedagogy. The incubators would provide an innovative mechanism to satisfy the “broad impact” mandate in research projects funded by the NSF.

Universities should place greater emphasis on awareness of new teaching methods, perhaps ear-marking a portion of research start-up packages to support attendance of incoming instructors at education workshops and meetings. Deans and department chairs at Michigan State University and University of Michigan have found that this strategy sends a message to all recruits that teaching is valued and it helps with recruiting faculty who are committed to teaching.

Distinguished researchers engaged in education reforms should exhort faculty, staff, and administrators to unite in education reform and should dispel the notion that excellence in teaching is incompatible with first-rate research. Federal and private funding agencies have contributed to this goal with programs such as the NSF’s Distinguished Teaching Scholar Award and the Howard Hughes Medical Institute Professors Program, which demonstrate that esteemed researchers can also be innovative educators and bring prestige to teaching.

Universities and professional societies need to create more vehicles for educating faculty in effective teaching methods. For example, the National Academies Summer Institutes on Undergraduate Education, the Council of Graduate Schools’ Preparing Future Faculty program, the American Society for Microbiology Conference for Undergraduate Educators, and Workshops for New Physics and Astronomy Faculty are steps toward this goal (3).

Finally, the reward system must be aligned with the need for reform. Tenure, sabbaticals, awards, teaching responsibilities, and administrative support should be used to reinforce those who are teaching with tested and successful methods, learning new methods, or introducing and analyzing new assessment tools. This approach has succeeded at the University of Wisconsin–Madison, which has rewritten tenure guidelines to emphasize teaching, granted sabbaticals based on teaching goals, and required departments to distribute at least 20% of merit-based salary raises based on teaching contributions (3).

If research universities marshal their collective will to reform science education, the impact could be far-reaching. We will send nonscience majors into society knowing how to ask and answer scientific questions and be capable of confronting issues that require analytical and scientific thinking. Our introductory courses will encourage more students to become scientists. Our science majors will engage in the process of science throughout their college years and will retain and apply the facts and concepts needed to be practicing scientists. Our faculty will be experimentalists in their teaching, bringing the rigor of the research lab to their classrooms and developing as teachers throughout their careers. Classrooms will be redesigned to encourage dialogue among students, and they will be filled with collaborating students and teachers. Students will see the allure of science and feel the thrill of discovery, and a greater diversity of intellects will be attracted to careers in science. The benefits will be an invigorated research enterprise fueled by a scientifically literate society.

**References and Notes**

1. AAAS, "Science for all Americans: A Project 2061 report on literacy goals in science, mathematics, and technology" (AAAS, Washington, DC, 1989).
3. Supporting online material provides further references on this point.
11. We thank C. Matta, C. Plund, C. Pribbenow, A. Fagen, and J. Labov for comments and A. Wolf for contributions to the supplemental materials. Supported in part by the Howard Hughes Medical Institute.

**Supporting Online Material**

www.sciencemag.org/cgi/content/full/304/5670/521/DC1

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**SCIENTIFIC TEACHING EXAMPLES**

<table>
<thead>
<tr>
<th>Group problem-solving in lecture</th>
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<td><a href="http://www.ibscore.org/courses.htm">www.ibscore.org/courses.htm</a></td>
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<td><a href="http://yucca.uoregon.edu/web/index.html">http://yucca.uoregon.edu/web/index.html</a></td>
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<td><a href="http://mazur-www.harvard.edu/education/educationmenu.php">http://mazur-www.harvard.edu/education/educationmenu.php</a></td>
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<tr>
<th>Problem-based learning</th>
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<td><a href="http://www.ncsu.edu/per/_scaleup.html">www.ncsu.edu/per/_scaleup.html</a></td>
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<td><a href="http://webphysics.iupui.edu/jitt/jitt.html">http://webphysics.iupui.edu/jitt/jitt.html</a></td>
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<th>Case studies</th>
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<td><a href="http://www.bioquest.org/lifelines/">www.bioquest.org/lifelines/</a></td>
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<tr>
<td><a href="http://brighamrad.harvard.edu/education/online/tcd/tcd.html">http://brighamrad.harvard.edu/education/online/tcd/tcd.html</a></td>
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<tr>
<th>Inquiry-based labs</th>
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<td><a href="http://www.plantpath.wisc.edu/fac/job/bbt.htm">www.plantpath.wisc.edu/fac/job/bbt.htm</a></td>
</tr>
<tr>
<td><a href="http://www.bioquest.org/">www.bioquest.org/</a></td>
</tr>
<tr>
<td><a href="http://biology.dbs.unm.edu/biol101/default.htm">http://biology.dbs.unm.edu/biol101/default.htm</a></td>
</tr>
<tr>
<td><a href="http://campus.murraystate.edu/academic/faculty/terry.derting/cccl/ccbllhomepage.html">http://campus.murraystate.edu/academic/faculty/terry.derting/cccl/ccbllhomepage.html</a></td>
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<tr>
<th>Interactive computer learning</th>
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<td><a href="http://www.bioquest.org/">www.bioquest.org/</a></td>
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<tr>
<td><a href="http://www.dna.org">www.dna.org</a></td>
</tr>
<tr>
<td><a href="http://evangelion.mit.edu/802TEAL3D/">http://evangelion.mit.edu/802TEAL3D/</a></td>
</tr>
<tr>
<td><a href="http://ctools.msu.edu/">http://ctools.msu.edu/</a></td>
</tr>
</tbody>
</table>
Handelsman, p. 1

**Science Supporting Online Material**

**POLICY FORUM: Scientific Teaching**

Jo Handelsman,1* Diane Ebert-May,2 Robert Beichner,3 Peter Bruns,3 Amy Chang,6 Robert DeHaan,7† Jim Gentile,6 Sarah Lauffer,1 James Stewart,2 Shirley M. Tilghman,9 William B. Wood10

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Bibliography: Further Reading about Scientific Teaching

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*To whom correspondence should be addressed. E-mail: joh@plantpath.wisc.edu
†Present address: Division of Educational Studies, Emory University, Atlanta, GA 30322, USA.

**REFERENCES DIRECTLY RELATED TO THE TEXT**

**Reports Calling For Education Reform**


**Effective Teaching Methods to Reach Diverse Students**

The Reinvention Center at Stony Brook, “Reinventing undergraduate education: Three years after the Boyer Report” [State University of New York (SUNY) Stony Brook, NY, 2003].


National Research Council, *BIO2010: Transforming Undergraduate Education for Future Research Biologists* (Committee on Undergraduate Biology Education to Prepare Research Biologists).


**Why Faculty Resist Change**


**Quantitative Evaluation of Active Learning**


J. C. Wright et al., Journal of Chemical Education 75, 986 (1998).

**Supplements to Traditional Lectures**


http://webphysics.iupui.edu/jitt/jitt.html (“Just in time teaching” computer-based course management)

**Replacing Lectures**


www.ncsu.edu/per/TestInfo.html

www.ncsu.edu/per/SCALEUP/Classrooms.html

Inquiry-Based Labs

Experiments and Data about Teaching Methods

Assessment Tools
M. E. Huba, J. E. Freed, Learner-Centered Assessment on College Campuses: Shifting the Focus from Teaching to Learning (Allyn & Bacon, New York, 1999).

National Science Foundation “Broader Impact”
www.plantpath.wisc.edu/fac/joh/incub.htm

Workshops on Teaching for Science Educators
www.preparing-faculty.org
http://www.academiessummerinstitute.org/

Changes in Reward System to Reinforce Teaching
Table S1. Examples of Scientific Teaching Methods.

<table>
<thead>
<tr>
<th>Method</th>
<th>References and Websites</th>
</tr>
</thead>
</table>
| Group brainstorming or problem solving in lecture | (S1, S2, S3)  
ConcepTests  
http://mazur-www.harvard.edu/education/educationmenu.php  
Integrated Biological Science Courses Organized around Research Experience (IBSCORE)  
www.ibscore.org/courses.htm  
Workshop Biology  
http://yucca.uoregon.edu/wb/index.html |
| Problem-based learning                | (S4, S5, S6)  
Problem-Based Learning  
www.udel.edu/pbl/  
Case Studies in Problem-Based Learning  
www.microbelibrary.org/newsletter/nltrs00.pdf  
Student-Centered Activities for Large Enrollment Undergraduate Program  
www.ncsu.edu/per/scaleup.html  
Just-in-time Teaching  
http://webphysics.iupui.edu/jitt/jitt.html |
| Case studies                          | National Center for Case Study Teaching in Science  
http://ublib.buffalo.edu/libraries/projects/cases/case.html  
LifeLines Online  
www.bioquest.org/lifelines/  
Harvard Medical School Case Studies  
http://brighamrad.harvard.edu/education/online/tcd/tcd.html |
| Inquiry-based labs                    | (S1, S2, S7)  
Biology Brought to Life: A Guide to Teaching Students to Think Like Scientists  
www.plantpath.wisc.edu/fac/joh/bbl1.htm  
The BioQUEST Curriculum Consortium  
www.bioquest.org/  
Introduction to Biological Inquiry and Analysis  
http://campus.murraystate.edu/academic/faculty/terry.derting/ccli/cclihomepage.html  
Project IBSCORE, University of Montana  
http://biology.dbs.umt.edu/biol101/default.htm |
| Interactive computer learning         | The BioQUEST Curriculum Consortium  
www.bioquest.org/  
DNA Interactive  
www.dnai.org  
Technology Enabled Active Learning (TEAL) Studio Project  
http://evangelion.mit.edu/802TEAL3D/  
http://ctools.msu.edu/ |
Table References


### Table S2. Teaching Materials and Online Resources.

<table>
<thead>
<tr>
<th>Teaching Materials and Online Resources by Subject Area</th>
<th>URL</th>
<th>Type of Material or Resource</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biology Brought to Life: A Guide to Teaching Students to Think Like Scientists</td>
<td><a href="http://www.plantpath.wisc.edu/fac/joh/bbtl.htm">www.plantpath.wisc.edu/fac/joh/bbtl.htm</a></td>
<td>Classroom activities, inquiry-based labs</td>
<td>These online book chapters offer ideas for cooperative exercises and inquiry-based labs that can be integrated into biology courses. Chapters include how-to instructions, rationale, and full-length labs with teacher guides.</td>
</tr>
<tr>
<td>BioQUEST Curriculum Consortium</td>
<td><a href="http://bioquest.org">http://bioquest.org</a></td>
<td>Multimedia</td>
<td>This collection of computer tools allows students to <em>pose</em> their own problems, solve these <em>problems</em> through investigations of their own design, and <em>persuade</em> their peers that their conclusions are correct: the BioQUEST “3 Ps.”</td>
</tr>
<tr>
<td>Concept mapping tool (CTOOLS)</td>
<td><a href="http://www.ctools.msu.edu">www.ctools.msu.edu</a></td>
<td>Multimedia (assessment)</td>
<td>This Web-based concept mapping tool provides students and faculty with a visual representation of principles and relationships among concepts. It includes computer-based scoring capabilities.</td>
</tr>
<tr>
<td>DNA from the Beginning</td>
<td><a href="http://www.dnaftb.org">www.dnaftb.org</a></td>
<td>Multimedia</td>
<td>This technology-rich Web site includes concept lists, graphics, animations, and more for teaching about DNA.</td>
</tr>
<tr>
<td>DNA Interactive</td>
<td><a href="http://www.dnai.org">www.dnai.org</a></td>
<td>Multimedia</td>
<td>This interactive Web site teaches students about the structure, function, and history of DNA through fascinating animations and problem-solving scenarios.</td>
</tr>
<tr>
<td>Frog Deformities</td>
<td><a href="http://www.first2.org/resources/inquiry_activities/frog_activity.htm">www.first2.org/resources/inquiry_activities/frog_activity.htm</a></td>
<td>Online activity</td>
<td>In this activity, students engage in experimental design and data analysis to understand complex interactions between environmental variables and frog populations.</td>
</tr>
<tr>
<td>Genetics Education Center</td>
<td><a href="http://www.kumc.edu/gec/">www.kumc.edu/gec/</a></td>
<td>Online resources</td>
<td>This Web site is designed for educators who are interested in human genetics and the human genome project. It includes links to lesson plans, the human genome project, networks, and programs.</td>
</tr>
<tr>
<td>Genome Consortium for Active Teaching (GCAT)</td>
<td><a href="http://www.bio.davidson.edu/Biology/GCAT/GCAT.html">www.bio.davidson.edu/Biology/GCAT/GCAT.html</a></td>
<td>Online activities</td>
<td>This online resource brings functional genomic methods into undergraduate curricula through student research and is a collection of information and data for teaching genomics.</td>
</tr>
<tr>
<td>Guppy Simulation</td>
<td><a href="http://www.first2.org/resources/inquiry_activities/guppy_activity.htm">www.first2.org/resources/inquiry_activities/guppy_activity.htm</a></td>
<td>Online activity</td>
<td>In this computer-based activity, students build understanding of natural selection, sexual selection, and fitness.</td>
</tr>
<tr>
<td>Integrated Biological Science Courses Organized around Research Experience (IBSCORE)</td>
<td><a href="http://www.ibscore.org/courses.htm">www.ibscore.org/courses.htm</a></td>
<td>Course materials</td>
<td>This course uses a teamwork approach that involves all students in a classroom, promotes critical thinking, and teaches communication skills in science.</td>
</tr>
<tr>
<td>Science Supporting Online Material</td>
<td>Handelsman, p. 7</td>
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<tr>
<td><strong>Introduction to Biological Inquiry and Analysis</strong></td>
<td><strong>Course materials</strong></td>
<td>In this course, students learn basic concepts in biology and engage in science as a process of active inquiry that serves as a framework for further study. The Web site includes 10 in-class assignments and an introduction to basic statistics.</td>
<td></td>
</tr>
<tr>
<td>LifeLines</td>
<td><strong>Online activities (case-based learning)</strong></td>
<td>This collection of online cases is designed by community college teachers and is based on real-life scenarios.</td>
<td></td>
</tr>
<tr>
<td>Microbes Count!</td>
<td><strong>Multimedia</strong></td>
<td>This collection of multimedia resources, simulations, and tools is an interactive, open-ended forum for learning about microbiology.</td>
<td></td>
</tr>
<tr>
<td>MicrobeLibrary</td>
<td><strong>Online activities</strong></td>
<td>This searchable portal provides a peer-reviewed, Web-based collection of resources about the microbial world, including visual images and animations, curriculum activities for both classroom and laboratory, and articles. The collection is linked directly to a recommended core curriculum for introductory microbiology education.</td>
<td></td>
</tr>
<tr>
<td>Problem-based Learning</td>
<td><strong>Online activities (problem-based learning)</strong></td>
<td>This collection of problem-based learning (PBL) activities challenges students to work cooperatively in groups to solve real-world problems.</td>
<td></td>
</tr>
<tr>
<td>Teaching Case Database</td>
<td><strong>Online activities (case-based learning)</strong></td>
<td>This collection of online cases is designed for medical students at Harvard Medical School.</td>
<td></td>
</tr>
<tr>
<td>Teams and Streams</td>
<td><strong>Inquiry-based labs</strong></td>
<td>These labs provide a framework for teachers to move from traditional, confirmatory approaches to student-driven inquiry. Students post results on Web sites of their own design.</td>
<td></td>
</tr>
<tr>
<td>Workshop Biology</td>
<td><strong>Course materials, resources</strong></td>
<td>This program is designed to improve biology teaching for non-biology majors. The Web site includes many resources, including a downloadable, 230-page curriculum development handbook, and more.</td>
<td></td>
</tr>
<tr>
<td><strong>Chemistry</strong></td>
<td><strong>Multimedia</strong></td>
<td>This collection of modules is designed to enhance the appreciation and learning of chemistry.</td>
<td></td>
</tr>
<tr>
<td>ChemLinks</td>
<td><strong>Classroom activities</strong></td>
<td>This Web site outlines strategies for teaching in a “workshop format” where teams of students are guided by a peer leader. This model provides an active learning experience for students, creates a leadership role for undergraduates, and engages faculty in a creative new dimension of instruction.</td>
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<td>Peer-led Team Learning</td>
<td><strong>Peer-led Team Learning</strong></td>
<td><strong>Classroom activities</strong></td>
<td><strong>Multimedia</strong></td>
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<tr>
<td><strong>Calibrated Peer Review</strong></td>
<td><a href="http://cpr/molsci.ucla.edu/">http://cpr/molsci.ucla.edu/</a></td>
<td>Online activities</td>
<td>This Web-based program provides resources for implementing frequent writing assignments in large classes with limited instructional resources.</td>
</tr>
<tr>
<td><strong>Just-in-time Teaching (JITT)</strong></td>
<td><a href="http://webphysics.iupui.edu/jitt/jitt.html">http://webphysics.iupui.edu/jitt/jitt.html</a></td>
<td>Multimedia</td>
<td>This program provides teacher resources and computer-based activities that use technology and problem-solving skills to improve learning. Students complete Web-based assignments prior to class so the instructor can revise teaching “just in time.”</td>
</tr>
<tr>
<td><strong>National Center for Case Study Teaching in Science</strong></td>
<td><a href="http://ublib.buffalo.edu/libraries/projects/cases/case.html">http://ublib.buffalo.edu/libraries/projects/cases/case.html</a></td>
<td>Online activities</td>
<td>This Web site offers instructions and rationale for case-based learning, and includes a collection of online cases for many science disciplines.</td>
</tr>
<tr>
<td><strong>National Institute for Science Education</strong></td>
<td><a href="http://www.wcer.wisc.edu/nise/">www.wcer.wisc.edu/nise/</a></td>
<td>Online activities and assessment resources</td>
<td>This institute provides literature about teaching and learning, strategies for improving science education, and assessment guides for teachers and students.</td>
</tr>
<tr>
<td><strong>Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP)</strong></td>
<td><a href="http://scaleup.ncsu.edu/">http://scaleup.ncsu.edu/</a></td>
<td>Multimedia</td>
<td>This program offers pedagogical methods and classroom management techniques that include hands-on activities, simulations, questions, problem-solving scenarios, and hypothesis-driven labs.</td>
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<tr>
<td><strong>Physics</strong></td>
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<tr>
<td><strong>Activity-based Physics</strong></td>
<td><a href="http://physics.dickinson.edu/~abp_web/abp_homepage.html">http://physics.dickinson.edu/~abp_web/abp_homepage.html</a></td>
<td>Multimedia</td>
<td>This suite of textbooks, computer software, and other materials is based on physics education research. The activity-based materials help students learn difficult physics concepts.</td>
</tr>
<tr>
<td><strong>Cooperative Group Problem Solving in Physics</strong></td>
<td><a href="http://groups.physics.umn.edu/physed/Research/CGPS/CGPSintro.htm">http://groups.physics.umn.edu/physed/Research/CGPS/CGPSintro.htm</a></td>
<td>Teaching strategies and inquiry-based labs</td>
<td>This Web site contains information about how to implement cooperative group problem-solving into physics classrooms, as well as a downloadable lab manual.</td>
</tr>
<tr>
<td><strong>Peer Instruction</strong></td>
<td><a href="http://mazur.www.harvard.edu/education/educationmenu.php">http://mazur.www.harvard.edu/education/educationmenu.php</a></td>
<td>Classroom activities</td>
<td>This article suggests strategies that can be used to embellish lectures with activities where students teach each other, as well as rationale for these activities, and ConcepTest examples.</td>
</tr>
<tr>
<td><strong>Physlets</strong></td>
<td><a href="http://webphysics.davidson.edu/Applets/Applets.html">http://webphysics.davidson.edu/Applets/Applets.html</a></td>
<td>Multimedia</td>
<td>This Web site and companion book contain physics problems with animated physics applets.</td>
</tr>
<tr>
<td><strong>Technology Enabled Active Learning (TEAL) Studio Project</strong></td>
<td><a href="http://evangelion.mit.edu/802TEAL3D/">http://evangelion.mit.edu/802TEAL3D/</a></td>
<td>Multimedia</td>
<td>These computer simulations are designed to help freshmen develop intuition about and conceptual models of physical phenomena. The tools are based on an active-learning approach that merges lecture, lab, and discussion sections. Course notes, graphics, and animations are available.</td>
</tr>
<tr>
<td>General Teaching</td>
<td>Bibliography</td>
<td>This comprehensive bibliography lists articles about active learning.</td>
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<td>The Active Learning Site</td>
<td><a href="http://www.active-learning-site.com/bib1.htm">www.active-learning-site.com/bib1.htm</a></td>
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<tr>
<td>Center for Science and Math Teaching</td>
<td><a href="http://ase.tufts.edu/csmt/">http://ase.tufts.edu/csmt/</a></td>
<td>Teaching strategies and resources.</td>
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<tr>
<td>Center for Teaching Effectiveness</td>
<td><a href="http://www.utexas.edu/academic/cte/resources/each.html">www.utexas.edu/academic/cte/resources/each.html</a></td>
<td>Teaching strategies and resources.</td>
<td></td>
</tr>
<tr>
<td>HHMI New Generation Program</td>
<td><a href="http://newgenerationprogram.wisc.edu">http://newgenerationprogram.wisc.edu</a></td>
<td>Teaching strategies and resources.</td>
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<tr>
<td>KnowledgeRoom Networks</td>
<td><a href="http://www.knowledgeroom.com/">www.knowledgeroom.com/</a></td>
<td>Teaching strategies and resources.</td>
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<tr>
<td>Biology Education Online (BEoN)</td>
<td><a href="http://www.accessexcellence.org/LC/BEoN/">www.accessexcellence.org/LC/BEoN/</a></td>
<td>This is an online, peer-reviewed journal for K-16 educators in the life sciences.</td>
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<tr>
<td>BioScienceEdNetwork (BEN)</td>
<td><a href="http://www.biosciednet.org">www.biosciednet.org</a></td>
<td>This digital, searchable database of biology instructional materials and resources is designed to help undergraduate educators to improve their teaching through resources, collaboration, and network building.</td>
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<tr>
<td>The Learning Matrix</td>
<td><a href="http://thelearningmatrix.enc.org/">http://thelearningmatrix.enc.org/</a></td>
<td>This site provides access to peer-reviewed digital resources that promote inquiry- and problem-based learning in college mathematics, science, and technology classes. Instructions are included for posting new instructional materials.</td>
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<tr>
<td>Multimedia Educational Resource for Learning and Online Teaching (MERLOT)</td>
<td><a href="http://www.merlot.org">www.merlot.org</a></td>
<td>This electronic database is a “free and open resource” of instructional materials, including peer reviews and comments. Instructions are included for posting new instructional materials.</td>
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<tr>
<td>National Science Digital Library</td>
<td><a href="http://nsdl.org/">http://nsdl.org/</a></td>
<td>This digital library contains resource collections and services for science, technology, engineering and mathematics education.</td>
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<tr>
<td>Science, Math, Engineering, and Technology Education</td>
<td><a href="http://www.smete.org/">www.smete.org/</a></td>
<td>This digital library offers access to online teaching and learning materials for students and teachers.</td>
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<td>Professional Society Web sites and other Publications</td>
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<tr>
<td>American Association for the Advancement of Science</td>
<td><a href="http://www.aaas.org/education/">www.aaas.org/education/</a></td>
<td>Education homepage</td>
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<tr>
<td>Organization</td>
<td>Website</td>
<td>Journals or Resources</td>
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<td>American Association of Physics Teachers</td>
<td><a href="http://www.aapt.org">www.aapt.org</a></td>
<td>Journals: <em>Physics Teacher</em> and <em>American Journal of Physics</em></td>
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<td>American Physiological Society</td>
<td><a href="http://www.the-aps.org/education/edu_ugrad.html">www.the-aps.org/education/edu_ugrad.html</a></td>
<td>Education homepage</td>
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<td>American Society for Cell Biology</td>
<td><a href="http://www.ascb.org">www.ascb.org</a> <a href="http://www.cellbioed.org">www.cellbioed.org</a></td>
<td>Online Journal: <em>Cell Biology Education</em></td>
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<td>American Society for Microbiology</td>
<td><a href="http://www.asm.org/education">www.asm.org/education</a></td>
<td>Journals: <em>Microbiology Education</em> and <em>ASM News</em></td>
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<tr>
<td>Association of College and University Biology Educators</td>
<td><a href="http://www.acube.org">www.acube.org</a></td>
<td>Journal: <em>Bioscene: Journal of College Biology Teaching</em></td>
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<tr>
<td>Ecological Society of America</td>
<td><a href="http://www.esa.org/education/">www.esa.org/education/</a></td>
<td>Education homepage</td>
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<tr>
<td>National Association of Biology Teachers</td>
<td><a href="http://www.nabt.org">www.nabt.org</a></td>
<td>Journal: <em>American Biology Teacher</em></td>
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<tr>
<td>Teaching Professor</td>
<td><a href="http://www.teachingprofessor.com">www.teachingprofessor.com</a></td>
<td>Newsletter about teaching methods and research</td>
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FURTHER READING ABOUT SCIENTIFIC TEACHING

Philosophy & Paradigm Shift


Theories


**Principles & Methods**


**Textbooks**


Other Compilations of Active Learning References

www.active-learning-site.com/bib1.htm

www.ncsu.edu/felder-public/