Learning at the Edge:

The Nature and Design of Inquiry-based Learning Environments for an Undergraduate Environmental Geoscience Program

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Abstract and Citation

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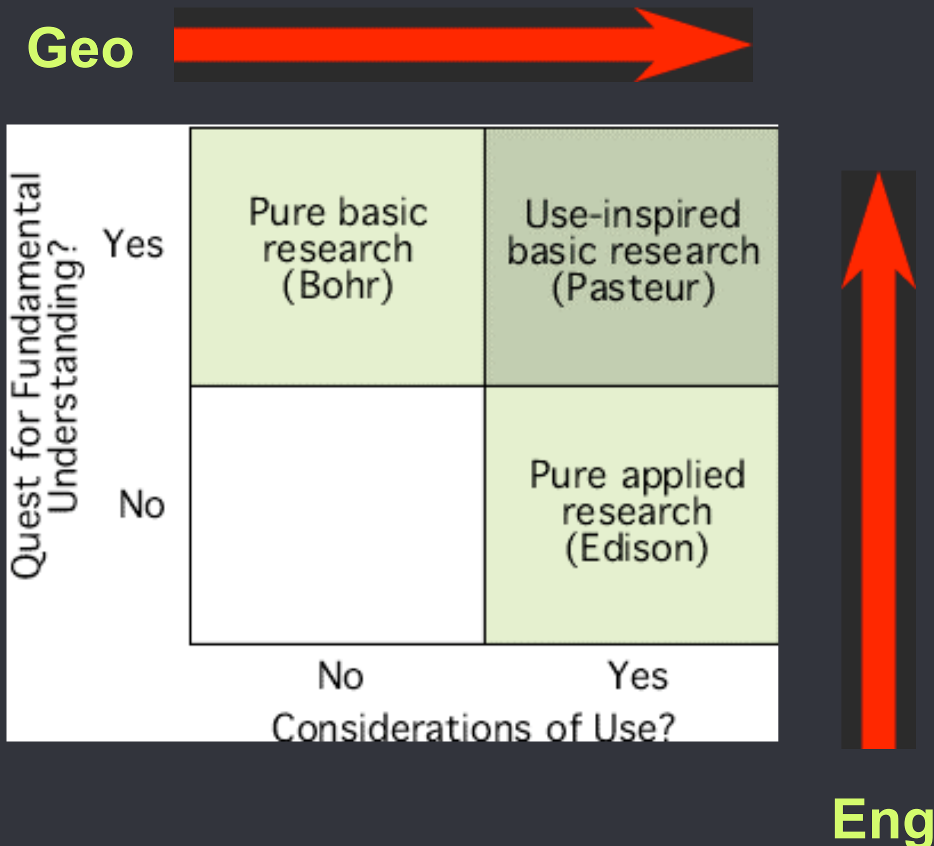
Abstract: As a research I institution, Texas A&M's Mission includes "providing the highest quality undergraduate and graduate programs", which "is inseparable from its mission of developing new understandings through research and creativity". This is a lofty goal that is not always achieved. A major initiative at TAMU is to embed inquiry experiences in all undergraduate courses, one of the best pedagogical practices to support the development of critical thinking skills and competencies in science learners including problem-solving, knowledge transfer, and decision making. Information technologies are often a central component of inquiry-based learning environments because these tools support student manipulation of data, the development and testing of conceptual models based on available evidence, and exposure to authentic, complex and ill-constrained problems. We are supporting this initiative through our participation in CIRTL (cirtl.net), an NSF-sponsored consortium of research institutions that seeks to develop a national STEM graduate student through faculty with the capability and commitment to implement and improve effective teaching and learning practices for all students.

This talk will discuss current efforts to develop and implement effective learning environments for the environmental geosciences programs at TAMU designed around inquiry-based (experiential) learning. I will discuss the complex nature and design of inquiry activities for geological and environmental sciences using the concept of "an environmental problem space". A problem space is defined as "a cohesive suite of rules, policies, practices, conventions, standards, concepts, etc. that govern the conceptual domain where a particular problem needs to be solved".

Finally, I will argue that authentic inquiry may serve as a boundary object to support structured synergy between research and teaching, serving to reduce the major dichotomy in faculty work. Boundary Objects (BO) serve as an interface between different groups in a community of practice. Boundary objects are flexible enough to adapt to local needs and have different distinct identities in different communities, but at the same time robust enough to maintain a common identity across the boundaries to be a place for shared work.

Geosciences and Environmental Engineering



Pasteur's Quadrant

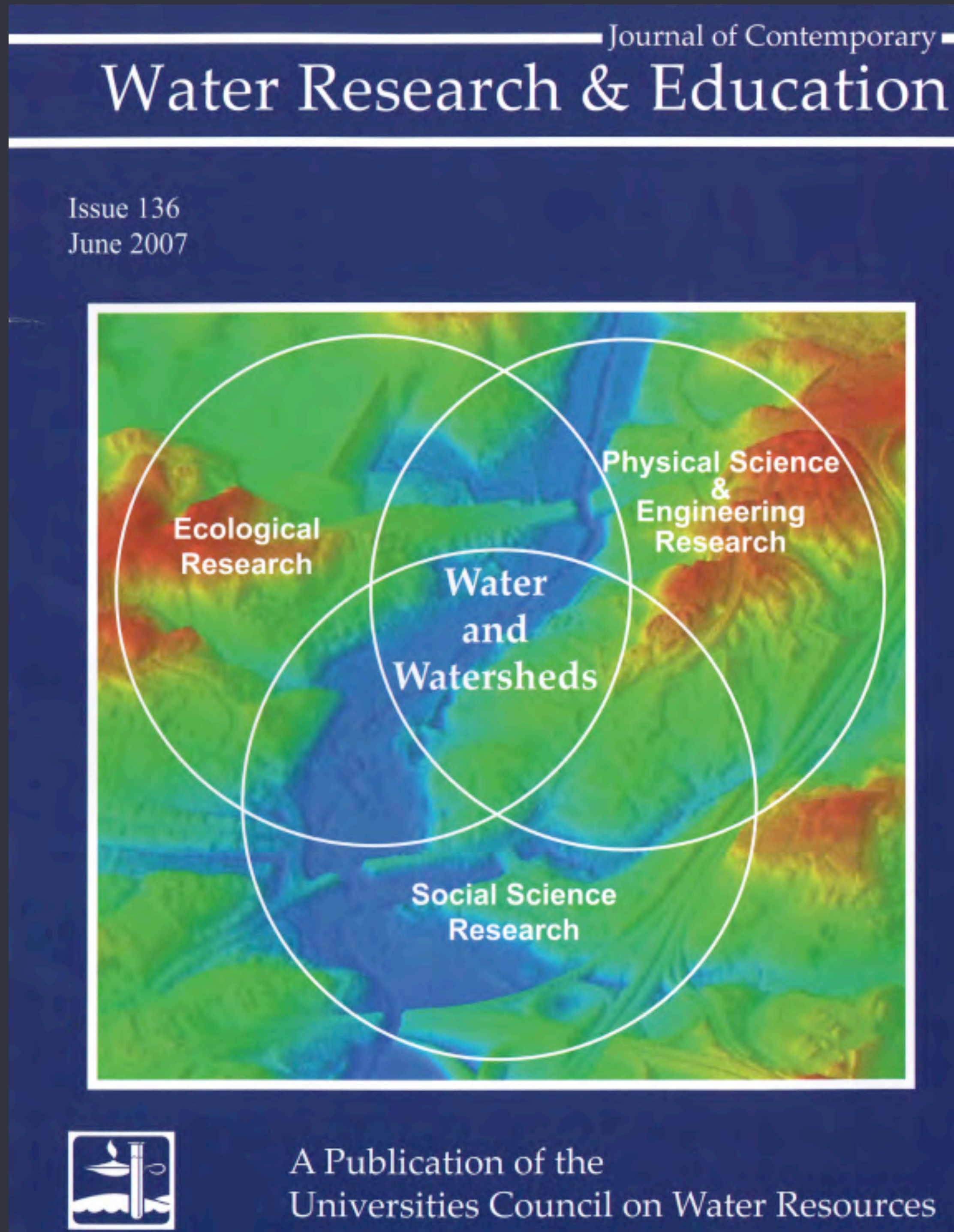
Stokes, 1997. Pasteur's Quadrant: Basic Science and Technological Innovation

- Engineered versus natural systems
- The goals of Eng are driven by social issues and problems
- Geosciences includes historical inquiry
- Eng inquiry includes design
- Both require certification

Texas A&M University

Learning Goals

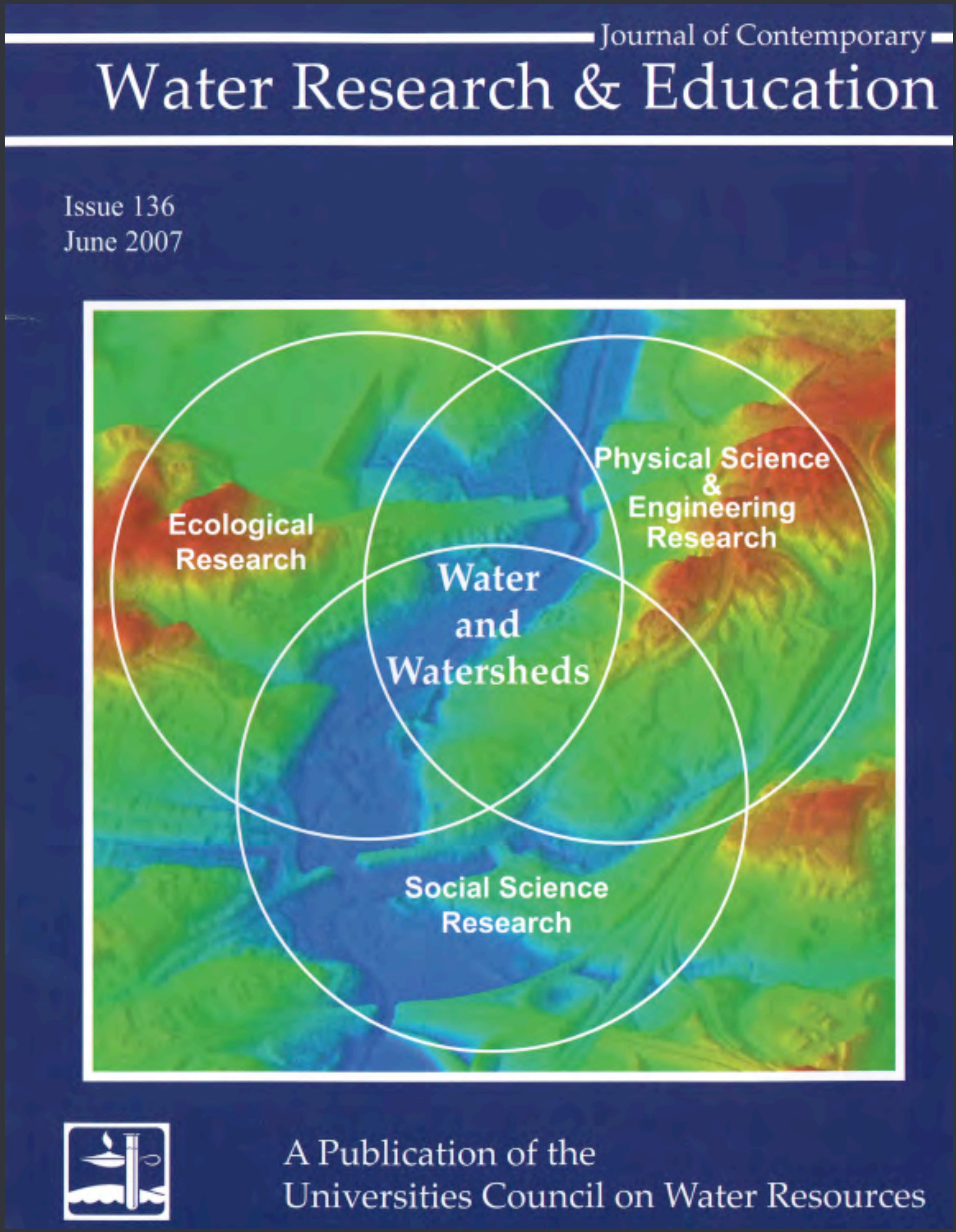
Environmental
Literacy
Agency
Professional/Career



Learning Issues

Knowledge transfer

Problem focused



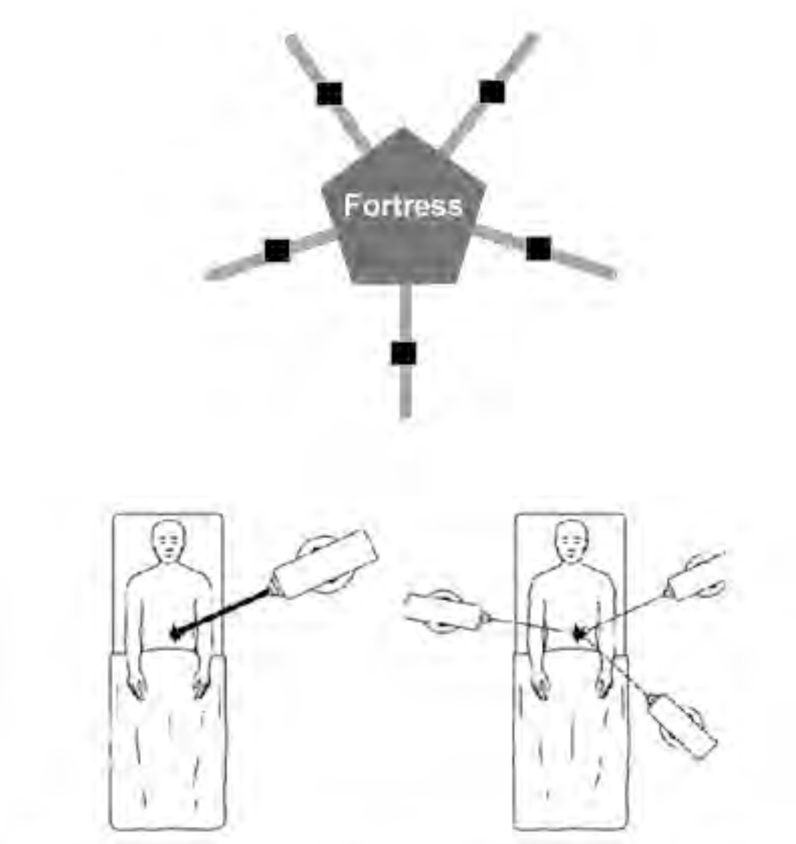
Student Learning

Knowledge Transfer

Knowledge transfer requires:

- Knowledge threshold
- Learning with understanding
- Knowledge taught in a variety of contexts
- Deliberate practice focused on meaningful questions (metacognitive skills)

Anderson et al., 1996. Situated learning and education. Ed. Researcher 25(4):5-11



Duncker's classic fortress/tumor analogic problem (Duncker, 1926)

Scientific Inquiry as Anchor

Learning activities focused on authentic inquiry/design act as anchors in interdisciplinary programs (Cognition and Technology Group at Vanderbilt)

Experience ↔ **Patterns** ↔ **Argument Justification**

Experience
- Data
- Observations
- Investigations
- Theory
- Phenomena
- Systems
- Objects
- Events

Patterns
- Evidence
- Trends
- Relationships
- Generalizations
- Theory
- Representations

Argument Justification
- Hypotheses
- Questions
- Theory
- Evidence-based Claims
- Models
- Predictions
- Explanations

Adapted from C.W. Anderson, National Association of Research in Science Teaching Presidential Address (2003))

Scientific Inquiry as Anchor

Learning activities focused on authentic inquiry/design act as anchors in interdisciplinary programs (Cognition and Technology Group at Vanderbilt)

	Traditional Hands-on	Structured Inquiry	Guided Inquiry	Student Directed Inquiry	Student Research Inquiry
Topic	Teacher	Teacher	Teacher	Teacher	Teacher/Student
Question	Teacher	Teacher	Teacher	Teacher/Student	Student
Materials	Teacher	Teacher	Teacher	Student	Student
Procedures/ Design	Teacher	Teacher	Teacher/Student	Student	Student
Results/ Analysis	Teacher	Teacher/Student	Student	Student	Student
Conclusions	Teacher	Student	Student	Student	Student

Engineering Design as Anchor

Learning activities focused on authentic inquiry/design act as anchors in interdisciplinary programs (Cognition and Technology Group at Vanderbilt)

Need Identification
Function
Constraints
Trade-offs
Systems
Objects
Events

↔

Conceptual Design
Abstraction
Design Evaluation
Failure Analysis
Solution Field

↔

Realization
Prototype
Impact Assessment
Communication
Redesign

Adapted from Lewis, T. 2006. J. Res. Sci. Teach 43(3):255-281

Implementing Authentic Inquiry

Implementing authentic inquiry requires development of instructional materials, learning activities, and assessment tools.

Simulated Research Tasks

"In this lab, you are to act as if you are an environmental consultant bidding and completing a project report for the federal government.

We will assume that the data on the server or USGS web sites is the data you have collected during your study. In this project, you are to write a proposal and a research report on a question of your choice concerning water quality in the South Platte River."

Sell, Herbert, and Stussey. 2006, J. Geosci. Ed 54: 396-407

South Platte Watershed Management Project

Implementing Authentic Inquiry

environmental geology

texas a&m university

WEBSITE HOME | GEOLOGY & GEOPHYSICS | TAMU

- Syllabus
- Lecture & Labs
- Library
- GIS
- Writing
- Class Members
- Comments

Watershed Management

This week we focus on watershed management. Watershed management is a set of activities that focus on the environmental quality of watersheds as geologic and environmental systems.

A wide range of indicators have been used by the EPA to characterize the quality of watersheds in the United States. View the latest data in map form.

Download the lectures (requires Adobe Acrobat Reader):

Nutrients and Surface Water Quality (11/10)

EPA Online Training in Watershed Management (11/17)

Ecosystem restoration: The Everglades Project (11/14)

South Platte Watershed Study (12/1)

The Watershed Initiative was conceived by the US EPA to encourage successful community-based approaches to restore, preserve, and protect the nation's watersheds. (Photo courtesy of EPA).

Required Readings

- EPA Online Training in Watershed Management
- Texas' Strategy for a Watershed Management Approach
- Stream Corridor Restoration: Principles, Process, and Practice

Additional Readings

- Contaminants in the Mississippi River, 1987-92
- Assessing the TMDL Approach to Water Quality Management
- EPA Watershed Quality Indicators

Case Study

- River Resource Management in the Grand Canyon (NAP)
- Downstream: Adaptive Management of Glen Canyon Dam and the Colorado River Ecosystem (NAP)
- Colorado River Ecology and Dam Management
- Science and the Greater Everglades (NAP)
- South Florida Ecosystem Restoration Task Force

Sell, Herbert, and Stussey. 2006, J. Geosci. Ed 54: 396-407

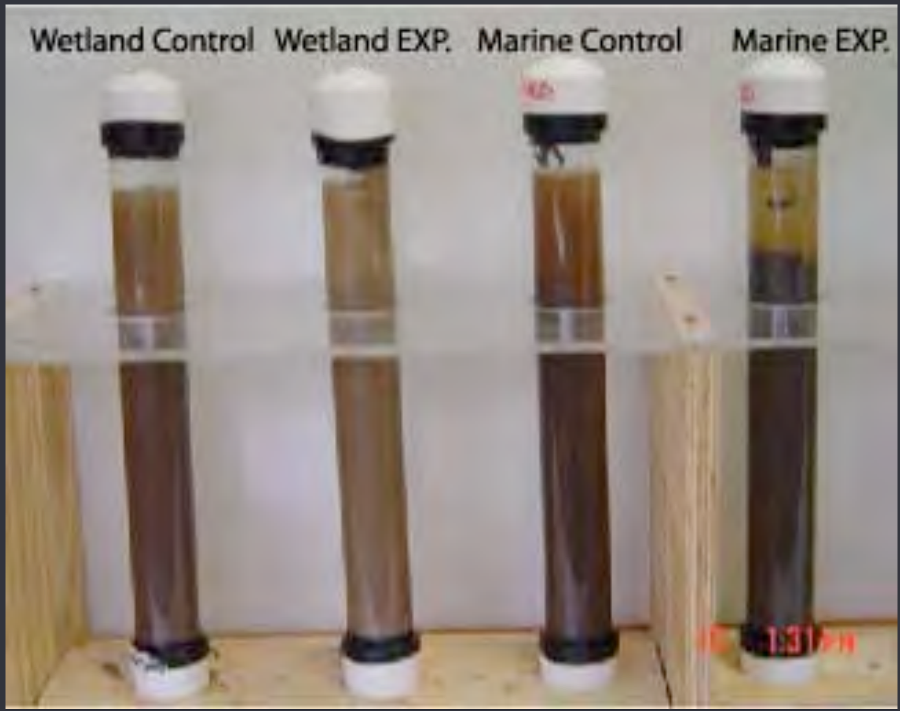
Implementing Authentic Inquiry

Implementing authentic inquiry requires development of instructional materials, learning activities, and assessment tools.

Simulated Research Tasks

- Experiments with physical models
- Experiments with computer simulations
- Analysis of complex data sets
- Evidence evaluation
- Verbal design / thought experiments

Sell, Herbert, and Stussey. 2006, J. Geosci. Ed 54: 396-407



Physical Models of Wetland Sediments

Inquiry/Design as Boundary Object

Scientific research can be transferred to the classroom through authentic inquiry:

- Scientific models & data sets
- Explicit description of cognitive and metacognitive skills
- New information technologies, research equipment, or tools
- Support communities of learning as content specialists.

Teaching through inquiry as a boundary object between research and teaching.

EDITORIAL

Rebalancing Teaching and Research

In universities across the United States and in many other parts of the world, the biological sciences continue to enjoy a wonderful revolution. Everything has changed in the research laboratory, but it is likely that far less has changed in the classroom down the hall. The same detachment of professor from student that frustrated university education 25 years ago is just as pervasive today. Although each course is now likely to have its own Web site, with class schedule, lecture notes, and assignments, the professoriate still struggles with how to use technology to achieve a greater impact on student learning and how to communicate the genuine excitement surrounding today's discoveries.

For this shortcoming we are paying a huge price: a decreasing percentage, here in the United States, of students who wish to pursue research careers; school districts that struggle to find qualified K-12 science teachers; and a public that has only a hazy understanding of the research advances that are sweeping through our society.

At the Howard Hughes Medical Institute (HHMI), we've recently empowered 20 outstanding teacher-scholars to make an impact on university education. These HHMI Professors, chosen through a nationwide competition,* are each being given $1,000,000 over 4 years to develop new modes of science teaching. Their approaches are diverse; in essence, they'll be carrying out 20 experiments in innovative education. Yet they share the common denominator of providing many more undergraduates with a real research experience. Other themes include teaching graduate students and postdocs how to teach; extending research experiences to high-school students and teachers; bridging biology with engineering, chemistry, and computer science; and engaging more underrepresented minorities in research.

For Jo Handelsman (right), a HHMI "million-dollar professor," research and teaching can't be separated.

How will their activities have a more general impact? The HHMI Professors will meet regularly to compare notes about what works in the classroom and what doesn't. Their best practices will then be broadly disseminated. We expect them to create Web- or DVD-based resources—including animations of biological processes and "virtual laboratories"—that encourage participatory learning. Furthermore, they will share successful curricula and materials by publishing in journals such as the new Web-based *Cell Biology Education*.†

Why do today's university faculty so rarely apply the same innovation and energy to their teaching that they invest in their research? There is no mystery here. Promotions, large salaries, and prestige at a research university are dependent on publications, patents, and grant funds. Good teaching may be appreciated, even applauded, but good research is at the heart of the reward structure. By providing recognition and research-level dollars to accomplished scientists who have a track record of exciting teaching and a penchant for more, we hope to tilt the research/teaching balance back to a healthy equilibrium.

These individual awards should enhance what is already going on at an institutional level. HHMI, the National Science Foundation, and others have nurtured undergraduate research through grants to both research universities and 4-year colleges for many years. Hands-on research experiences, though inherently inefficient with respect to faculty effort per student, are strikingly effective in their impact on young people's lives. We now have the opportunity to extend such experiences from independent research projects, often carried out by science majors in the junior or senior year, to core projects for many more students, preferably beginning much earlier in their undergraduate careers.

Reinvigoration of science teaching at research universities will benefit students, of course, but faculty will also find new stimuli for their research. G. N. Lewis's invention of the electron dot system for depicting chemical bonding while teaching introductory chemistry at the University of California, Berkeley, is a story that has been repeated with countless variations over the years. Students' questions force faculty to read and think outside their narrow field, often expanding or revising their approach to research problems. Above all, faculty members find great personal satisfaction in excelling at the activity that gives real meaning to the title "professor."

Thomas R. Cech

Thomas R. Cech is president of the Howard Hughes Medical Institute and for 22 years has been a teacher of undergraduates at the University of Colorado, Boulder.

*See www.hhmi.org †See www.cellbioed.org and pubmedcentral.nih.gov

www.sciencemag.org SCIENCE VOL 299 10 JANUARY 2003 165

Science, 10 January 2003

Myth of the Teacher-Scholar

TABLE 1

Productivity Measures by Type of Institution

	All 4-Year		Research		Doctoral		Comprehensive		Liberal Arts		Other	
	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*	Mean	*SE*
Research Productivity												
Publications, 2-year	3.850	0.068	5.780	0.179	3.840	0.128	2.060	0.072	1.741	0.142	4.890	0.338
Principal investigator (%)	28.840	0.557	47.300	1.374	27.470	1.209	12.140	0.601	11.110	1.316	35.910	2.375
Research dollars ($)	172,655	10,509	198,654	17,391	176,052	28,244	70,840	7,690	77,929	20,339	179,123	24,485
Conference presentations, 2-year	4.060	0.084	5.440	0.218	4.160	0.182	2.940	0.103	1.990	0.193	4.300	0.350
Teaching Productivity												
Student contact hours	328.940	5.665	317.650	15.241	328.300	12.778	335.330	6.655	249.760	10.576	470.500	31.471
Independent study contact hours	6.500	0.131	7.560	0.273	6.140	0.229	5.600	0.214	4.720	0.495	8.070	0.574
Thesis/dissertation committees	4.730	0.108	7.290	0.296	5.070	0.211	2.820	0.133	1.860	0.173	2.460	2.510
Instructional Approach												
Proportion using collaborative/active instruction	0.252	0.005	0.189	0.011	0.227	0.011	0.317	0.009	0.342	0.020	0.171	0.021

SOURCE: NSOPF 1993

Fairweather, J.S. 2002. J. Higher Education 73(1): 26-48

Myth of the Teacher-Scholar

TABLE 4

Percentage of faculty productive in both teaching and research

	All 4-Year		Research		Doctoral		Comprehensive		Liberal Arts	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
High Research & Teaching	22.09	0.53	21.69	1.21	21.54	1.15	22.79	0.79	20.40	1.73
High Res. & Teach + Pedagogy	5.96	0.31	4.59	0.63	4.05	0.57	7.90	0.52	8.07	1.20

Fairweather, J.S. 2002. J. Higher Education 73(1): 26-48

Final Thoughts

- Inquiry/Design as anchor in interdisciplinary programs
- Inquiry/Design as boundary object integrating research and teaching (achieve the teacher-scholar ideal)
- Hiring patterns leading to mission separation in research universities and undergraduate institutions?

Sandra Metoyer, a biology teacher prepares a geospatial database of coastal ecosystems during the ITS Summer Institute

Information Technology in Science, Center for Learning & Teaching (http://its.tamu.edu)