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Science 101: Building the Foundations for Real Understanding

Two online projects offer one-stop shopping for teaching evolution, as well as the nature and process of science.

Anastasia Thanukos,[1] Judith G. Scotchmoor,[1] Roy Caldwell,[1,2]† David R. Lindberg[1,2]

It's not just about evolution anymore. Growing anti-science sentiment in the United States now infuses public discourse on conservation, vaccination, distribution of research funds, and climate change (*1*). Low rates of scientific literacy (*2*) exacerbate the problem. Although the public recognizes its indebtedness to the products of scientific knowledge, few understand much about the nature of that knowledge or the processes that generated it (3). Without a basic understanding of how science works, the public is vulnerable to antiscience propaganda, which engenders distrust of science when it comes to social issues, consumer choices, and policy decisions.

Teaching the process of science. Mark Stefanski, a teacher adviser, uses the Science Flowchart with high-school biology students at Marin Academy, where the science faculty employs the flowchart in lab activities to help students focus on the process of science.

The University of California Museum of Paleontology's interest in this issue stemmed from a project on evolution education, which expanded into an effort to support more effective teaching of the nature and process of science (see the first figure). In 2000, we hosted a conference on evolution instruction that brought together stakeholders from education, academia, and the media. Participants identified a critical need for a collection of vetted tools for teaching evolutionary biology. Understanding Evolution (www.understandingevolution.org) was built, in collaboration with the National Center for Science Education, to meet this need and to provide a clear and comprehensive reference for the general public.

Understanding Evolution brought together an advisory board of scientists, Web designers, authors, and master teachers to create a vision for the project and develop content. Key aspects of this process included teacher guidance on content types, Web features, and pedagogy; review and editing by scientific experts; field testing through teacher advisers; revision of materials with additional expert review; and summative evaluation performed by the evaluation firm Rockman *et al.* (*4*).

The result of this process was the Understanding Evolution Web site, which provides educational materials targeting teachers of kindergarten through college, students, and the general public (see the second figure). Teacher advisers requested resources that engage students with data, explore scientific reasoning and science as a human endeavor, and demonstrate the relevance of evolution to everyday life. Site resources that respond to these needs include (i) "Evo in the News," a monthly feature that reveals the evolutionary science behind a current news story and integrates data from the primary literature with discussion questions and background reading; (ii) research profiles and case studies, which follow a particular scientist or investigation and step students through the logic of testing evolutionary hypotheses; and (iii) interactive investigations (e.g., Visualizing Life on Earth, http://evolution.berkeley.edu/evolibrary/article/ldg_01) that ask students to put scientific reasoning into practice. Many such resources will be housed in our Undergraduate Library, an area devoted to college-level evolution instruction, which will open in January 2011.

Since its launch in 2004, Understanding Evolution's impact has grown. The site now averages more than a million page accesses per month during the academic year, is available in Spanish and Turkish (www.sesbe.org/evosite/evohome.html, www.evrimianlamak.org/e/Ana_Sayfa), and has been distributed in Tibetan as part of the Dalai Lama's Emory-Tibet Science Initiative. Additionally, site resources have been shown to improve teachers' and students' understandings of evolution and to increase instructors' confidence in their ability to teach this challenging, and sometimes charged, material (*4*).

As we developed Understanding Evolution and noticed similar tensions and misinformation arising around topics like climate change, we realized that much of the public's mistrust of evolution stems from more basic and even more important issues: poor understanding of how science works to build reliable knowledge and confusion about the strengths and limitations of this process. Hence, we envisioned a Web site that would leverage the format of Understanding Evolution toward the goal of helping teachers reinforce the true nature and process of science throughout their teaching.

The Understanding Science Web site (www.understandingscience.org) was launched in January 2009. Its development process followed that for Understanding Evolution, bringing together scientists, philosophers of science, teachers, writers, and Web designers to conceive, develop, and vet content. The site is unique in its straightforward presentation of science, not as an esoteric collection of vocabulary and facts, but as an intensely human endeavor—a multifaceted process that both students and scientists can use to better understand the natural world. Instead of oversimplifying science into a five-step recipe, the site emphasizes the dynamic and iterative nature of the process, as well as the roles of creativity and community in scientific progress. Understanding Science is designed to give students and the general public the tools they need to recognize the relevance of science to their lives and to keep pace with the ways in which science informs personal and societal decision-making. These ideas are communicated through

[1]University of California Museum of Paleontology, University of California, Berkeley, Berkeley, CA, 94720–4780, USA. [2]Department of Integrative Biology, University of California, Berkeley, Berkeley, CA, 94720–4780, USA.

*SPORE, *Science* Prize for Online Resources in Education; www.sciencemag.org/special/spore/.

†Author for correspondence. E-mail: rlcaldwell@berkeley.edu

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a friendly primer on the nature of science, as well as through "Science in Action" features, which use stories from the history of science, animations, and graphics to reinforce basic scientific concepts and show how science works.

By providing a comprehensive, practical resource for teaching the nature and process of science, Understanding Science also fills a major gap in the landscape of science education materials. Teaching resources on the site (second figure) are informed by educational research showing that instruction in this area is most effective when it is explicit, reflective, and reinforced in many contexts (*5*). Three tools from the site help teachers put these guidelines into practice in multiple instructional settings. The Science Checklist helps students identify key characteristics of science in different investigations. The Science Flowchart provides a more accurate and appealing representation of the scientific process than the rigid Scientific Method. The Science Toolkit helps students analyze policies and media messages to get to the science behind the spin.

About the Authors

From left to right: **Roy Caldwell**, **Josh Frankel**, **David R. Lindberg**, **Judith G. Scotchmoor**, **Anastasia Thanukos**, and **David Smith**. R. Caldwell and D. R. Lindberg, co-principal investigators on the project, are curators in the University of California Museum of Paleontology (UCMP) and professors of Integrative Biology at the University of California, Berkeley. J. G. Scotchmoor, project coordinator, is an assistant director at UCMP, in charge of education and outreach. A. Thanukos, primary author, is principal editor at UCMP. J. Frankel and D. Smith work in education and outreach at UCMP and direct Web design for the project.

Although less than 2 years old, Understanding Science has had far-reaching impacts and now averages more than 60,000 page accesses per month during the school year. The project is endorsed by organizations such as the American Institute of Biological Sciences, and materials from the site have been incorporated into middle- and high-school textbooks from major publishers. Encouragingly, an evaluation of a year-long in-service training program indicates that site materials generate a high level of teacher buy-in, meaningful increases in student understanding, and reports of increased student motivation (*6*).

In the current climate of both funding constraints and concern for the future of science education in the United States, we see opportunities for additional contributions from these projects, such as new resources and collaborations with scientists, as well as challenges, such as maintaining vibrant and freely accessible teaching materials while seeking a sustainable funding model. Fortunately, many other initiatives have also set their sights on improving science literacy (*7*), and this complements a growing movement within the scientific community itself to reach out to students and the broader public. We are proud to be a part of this campaign and are committed to working with scientists, scientific agencies, the media, and educators to build a more scientifically literate society.

EDUCATIONAL RESOURCES AVAILABLE THROUGH UNDERSTANDING EVOLUTION AND UNDERSTANDING SCIENCE

Resource	Target Audience			
Understanding Evolution	Students	K–12 Teachers	Undergraduate Instructors	General Public
Searchable lesson database		●	●	
Tips, strategies, and teaching help		●	●	
Common misconceptions and explanations		●	●	
Conceptual framework		●	●	
Image library		●	●	
Evolution 101 and basic content	●	●	●	●
Advanced tutorials	●	●	●	●
Interactive online labs	●	●	●	
Research profiles and case studies	●	●	●	●
Evo in the News articles	●	●	●	●
Understanding Science				
Individual lessons and activities		●	●	
Searchable lesson database		●	●	
Tips, strategies, and teaching help		●	●	
Guidelines for modifying lessons		●	●	
Tips from the education research literature		●	●	
Common misconceptions and explanations		●	●	
Conceptual framework		●	●	
First-hand instructor reports			●	
Understanding Science 101 and basic content	●	●	●	●
Advanced supplementary content	●	●	●	●
Science in Action stories	●	●	●	●

● Currently available ● Launching this academic year

Educational resources. The Understanding Evolution and Understanding Science Web sites offer a wealth of resources for teaching and learning evolutionary biology and the nature and process of science. K–12, kindergarden to high school.

PHOTO CREDIT: MOLLY WRIGHT/UCMP

References and Notes

1. C. Mooney, S. Kirshenbaum, *Unscientific America* (Basic Books, New York, 2009).
2. R. Bybee, B. McCrae, R. Laurie, *J. Res. Sci. Teach.* **46**, 865 (2009).
3. National Science Board, Science and Engineering Indicators 2010 (National Science Foundation, Arlington, VA, 2010).
4. Rockman *et al.*, Understanding Evolution Evaluation, http://evolution.berkeley.edu/evolibrary/evaluation.php.
5. N. G. Lederman, in *Handbook of Research on Science Education*, S. K. Abell and N. G. Lederman, Eds. (Lawrence Erlbaum Associates, Mahwah, NJ, 2007), pp. 831–880.
6. M. A. M. Stuhlsatz, *Final Evaluation Report for the University of California Museum of Paleontology: Understanding Science* (ER 2010-08, Biological Sciences Curriculum Study, Colorado Springs, CO, 2010); http://undsci.berkeley.edu/BERKreport_7_12_10.doc.
7. American Association for the Advancement of Science, Center for Public Engagement with Science and Technology, www.aaas.org/programs/centers/pe/.
8. Supported by the NSF 0096613, EAR-0624436, DUE-0918741; Howard Hughes Medical Institute 51003439; and the University of California Museum of Paleontology.

Published online 2 December 2010; 10.1126/science.1186994

Published by AAAS