SPORE* SERIES WINNER

Using Video to Build Learning Contexts Online

An online course takes a systems approach to teaching Environmental Science.

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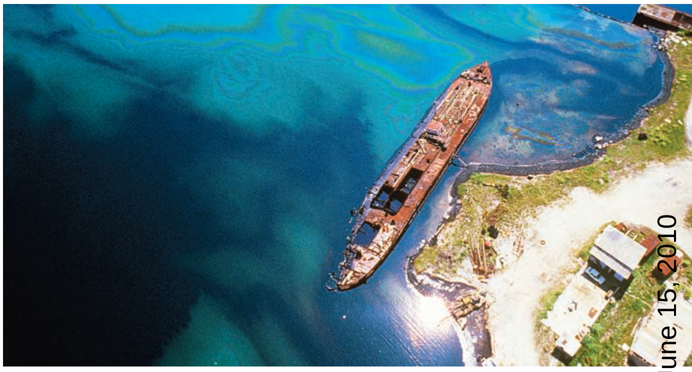
In recent years, the number of online courses has shown explosive growth, which has allowed students to participate in opportunities for higher education while eliminating the traditional constraints of scheduling, cost, and location. The Science Media Group at the Harvard-Smithsonian Center for Astrophysics has contributed to this growth by investigating how to make effective use of video-based materials to convey difficult ideas in science. One of our most recent productions, created in partnership with Annenberg Media, is a series of online course materials on environmental science.

A course designed to improve environmental science literacy for all adult learners and to serve the professional development needs of high school science teachers, The Habitable Planet: A Systems Approach to Environmental Science (www.learner.org/courses/envsci/) provides a road map to current environmental science issues. The course considers the Earth in a planetary context, one in which large geochemical cycles and transfers of energy in the atmosphere and ocean shape the habitat in which we live. The content for the course was developed by our colleagues at the Harvard University Center for the Environment, in collaboration with many world leaders in the field of environmental science. All course materials are offered without charge by Annenberg Media, via learner.org, a Web site offering a large collection of multimedia resources for students, teachers, and adult learners.

The conceptual backbone of the course consists of 13 units that cover key ideas in environmental science. Faculty from different fields in environmental science specified the scientific content and then closely edited several rounds of drafts written by a journalist with expertise in environmental science, which allowed us tap into knowledge at the frontiers of environmental science from more than a dozen individuals, but to maintain a consistent voice in the final product. A carefully crafted Web navigation system allows users to browse the content in whatever order suits their needs and to access its diverse components (which include text, video, interactive laboratories, animations, and graphics) (see the photo, right) from anywhere within the course.



The Habitable Planet online Environmental Science course. Topics addressed include research on factors that affect ecosystems, such as the effects that an oil spill off of the island of Tobago in the Caribbean Sea (July 1979 to March 1980) had on the distant coral reefs and mangrove ecosystems in Panama.

Online instruction has been part of science educators' professional lexicon for but a few decades, and our understanding of how to use this medium effectively is rapidly changing. One lesson our group has learned is that using this medium to teach for understanding can be extraordinarily difficult. Our foray into this field began with *A Private Universe* (*1*), a video famous for its scenes of Harvard graduates struggling with "simple" concepts in science (e.g., the causes of the seasons). This video, together with the online courses we developed as part of the Private Universe Projects in Science (*2*) and Mathematics (*3*), demonstrates that, even under the best of circumstances, students all too often fail to adopt the scientific understanding intended by the instructor. Such challenges may only be exacerbated in online settings where student-teacher interactions are often curtailed.

One of the reasons science learning may be difficult is that there is a conceit implicit in the traditional approach to instruction that conflicts with the way we make sense of scientific ideas. All too often instruction assumes that students build knowledge sequentially, from one prerequisite idea to the next, in a linear, hierarchical manner that mirrors the design of traditional textbooks and lectures. In real life, however, we tend to advance our understanding through a process that is much more haphazard and stochastic. Our knowledge builds from conflicting ideas (often only partially formed) that we weigh, one against the other, so that the understanding that emerges is the weighted sum of probabilistic beliefs. Thus, while the traditional approach to instruction presents ideas in a linear progression, we make sense of this material through a process that is much more malleable and fluid and is subject to many more influences than we currently understand or acknowledge.

The scientific process is difficult to convey by words alone. A video in The Habitable Planet shows scientists working with the Smithsonian Tropical Research Institute measuring seedlings to study changes in species diversity in the rainforest of Panama.

This process of nonlinear reasoning, inherent in science, mirrors how the human brain makes meaning from sensory inputs. For example, our eyes perceive the world as being

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stable and connected, despite the fact that our vision is interrupted by dramatic shifts in gaze direction that alter the visual aspect of the scene presented to the brain (*4*). Furthermore, although we imagine we see the world to be sharp and detailed everywhere, in reality only a very small patch in our vision (roughly 2° across) perceives the world at the level of clarity matching our beliefs (*5*). It is remarkable that, despite the fact that our senses present only an imperfect sample of information to our brain, the world we believe we see is detailed and contiguous. Clues as to why this is the case can be found in the literature on visual attention (*6*), which suggests that information that is sampled peripherally is augmented by higher-order conceptual frameworks, built from experience, that act to fill in detail missing in our senses (*7*). Even at the level of perception, our brains appear to be wired so as to resolve ambiguity—actively filling in detail with information that is peripherally observed— to build an understanding that is consistent with our experience.

The Habitable Planet gives an overview of the Earth's systems—geophysical, atmospheric, and oceanic systems, as well as ecosystems—as they exist independently of human influence. It builds on this theoretical presentation through the inclusion of videos that extend the text to tell stories of scientists engaged in cutting-edge research. These case studies afford students an opportunity to tag along on virtual visits to the field or to the research laboratory, to expose them to a level of "messy" peripheral detail we feel is essential for learning (*8*). The videos define a broad (often visual) context that serves as counterpoint to the linear structure defined by the narrative text, to help learners make sense of ideas they may only partially understand (see the photo on page 1119, bottom).

One compelling video depicts the process a glaciologist uses to gather evidence of changes in global temperatures across geologic time and shows how a team drills deep into tropical glaciers to extract ice cores holding the history of atmospheric conditions over centuries. The video shows how scientists take ice from the drill tubes, sort and label it, and then slice it to analyze samples for isotopic signatures of temperature change.

Voice-over commentary serves to move the video's linear narrative forward. At the same time, the video also provides a great deal of other more amorphous content, to quickly paint a broad picture of the experimental process at a level of detail that would be difficult, if not impossible, to convey in words. In the example of the video on glacial ice cores, we see what controls the scientists use to prevent contamination of their samples, and even get an appreciation of the temperatures involved by observing the brittleness of the ice as it is cut, all without any need for explicit exposition. In this way, the videos help advance the learners' understanding through a process that is more stochastic than what is possible in a traditional treatment, such as what a textbook or lecture might offer alone.

An important reason, perhaps intangible to the user, that the videos are so effective is that they were produced through a collaborative process between the faculty responsible for the text and the producers responsible for the video. Discussions between the two led to the selection of the subjects for the videos, and continued interaction ensured that the videos addressed key ideas vital to the learning goals of the course. The resulting programs, presented as case studies, put a human face to the research and provide a close-up look at the methodologies underlying the science, while offering a panoramic view of the frontiers of environmental research as it appears today. Topics range from how air samples obtained from around the globe document the rise in atmospheric CO_2 concentrations to how observations of wolves in Yellowstone demonstrate that changes in a single species alter the distribution of plants and animals across the food web. The videos depict subjects of pressing concern (biodiversity, water and energy resources, overfishing, and climate change) by focusing on essential questions whose answers are not yet known, to show how scientific teams, driven by a passion for knowledge, collect their data and carry out research.

The Habitable Planet supplements the instruction provided through text and video with interactive laboratory simulations that challenge users to systematically experiment with models of environmental systems. These interactive laboratories simulate systemic trade-offs, such as predator-prey relations or the impact of energy on atmospheric CO_2. In addition, the course includes a professional development guide to assist those using the course for teacher education.

Our course in Environmental Science has so far proved extremely popular, and in February 2010 alone, its Web site recorded more than 200,000 page views. Our plans are to extend these developments in our next course offering (to be released in 2010), Physics for the 21st Century, which will help undergraduates learn about ideas such as dark energy and black holes, ideas that occupy the interests of physicists working today. We will follow this with a course on Learning and the Brain (to be released in 2011). This course, targeting preservice and in-service teachers, will examine how an understanding of cognitive processes in the brain can inform teaching—ideas we ourselves hope to apply in our design to thus refine our models for effective online instruction.

Author Biographies

Alex Griswold (left) is a television producer and executive producer of the Science Media Group (SMG). Nancy Finkelstein (right), a veteran classroom teacher, was project manager of The Habitable Planet, among numerous other productions of the SMG. Matthew Schneps (center) is a physicist and science educator, founding director of SMG, and the principal investigator for this project. Not pictured are Michele McLeod, program director for Annenberg Media, and Daniel Schrag, who directs the Harvard University Center for the Environment and oversaw the development of the course content.

References and Notes

1. M. H. Schneps, P. M. Sadler, *A Private Universe* (Annenberg Media, Washington, DC, 1987), video; www.learner.org/resources/series28.html.
2. M. H. Schneps *et al*., Private Universe Project in Science (Annenberg Media, Washington, DC, 1995); www.learner.org/resources/series29.html.
3. M. H. Schneps *et al*., Private Universe Project in Mathematics (Annenberg Media, Washington, DC, 2000); www.learner.org/resources/series120.html.
4. D. Melcher, C. L. Colby, *Trends Cogn. Sci.* **12**, 466 (2008).
5. S. J. Galvin, R. P. O'Shea, A. M. Squire, D. G. Govan, *Vision Res.* **37**, 2035 (1997).
6. A. Oliva, in *Neurobiology of Attention*, L. Itti, G. Rees, and J. K. Tsotsos, Eds. (Elsevier, North Holland, 2005), chap 41.
7. H. Intraub, M. Richardson, *J. Exp. Psychol. Learn.* **15**, 179 (1989).
8. R. Driver, E. Guesne, A. Tiberghien, *Children's Ideas in Science* (Open Univ. Press, Milton Keynes, UK, 1985).
9. Habitable Planet is the result of a collaborative effort involving a great many individuals. Scientists who contributed to this work are listed at www.learner.org/courses/envsci/scientist, and the people responsible for the production and design can be found at www.learner.org/courses/envsci/about/credits.php.

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