Web-Enabled Learning Environments

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The web marries two important information technology capabilities: communication and computation. In the first case, web communication enables distributed access to a variety of learning resources, e.g., data sets, both real-time and archival; remote instrumentation; educational support tools; and perhaps most importantly, people. Shared access to such resources promotes the formation of communities of learning. In the second case, enormous computational power is now embedded in the web, both on the individual desktop and in the emerging paradigm of distributed or "grid" computing. This enables sophisticated graphical representations, animations, interactive simulations, and other virtual environments for learning.

These capabilities have numerous implications for improved STEM learning. For example, students may work with advanced instrumentation that is not available at their own institution or they may work with real data sets from leading-edge research studies—opportunities for authentic practice and inquiry that were impossible even 5 years ago. Likewise, the assessment of learning gains is another area that has seen the introduction of new techniques: both self and externally administered. These often feature the ability to provide many related yet still individualized suites of problems or examples to large numbers of students. Automatic grading or other feedback mechanisms are built in, as well as data gathering, so that student responses may be analyzed to understand the progress of overall class learning. Finally, virtual simulations of laboratory settings illustrate a third way in which the web's communication and computational capabilities offer new learning modalities. Dangerous or expensive experiments may be performed in this manner, but these environments also enable accelerated execution of the physical laboratory procedures so that students can have many more opportunities to undertake the full cycle of experimental design, evaluation of results, and then experimental redesign.

Over the last 5 years, the CCLI program has supported projects in a number of these areas. In the examples that follow, Porter explores the use of scientific data sets in biology education to provide opportunities for students to develop data analytical skills and habits of quantitative thinking. Ziemer then describes an online system for administering and automatically grading student homework. Originally developed for use in mathematics courses, the WeBWorK system has seen adoptions in other disciplines as well. The remaining two articles report on the use of virtual or simulated laboratory environments to support both the teaching of the scientific method and conceptual learning. These projects take place in genetics (Bell) and chemistry (Yaron et al.).

Even as innovations such as these become more widely known and implemented more broadly, advances in information technology continue to offer more possibilities for new learning tools and environments. Emerging 3D printing technology provides one particularly stunning example. Here, physical replicas of artifacts may be reproduced from data sets created by high-resolution X-ray computed tomographic scanning of objects (see http://www.digimorph.org) or, in other cases, stereo lithographic files derived from CAD representations (see http://techreports.library.cornell.edu:8081/Dienst/UI/1.0/Display/cul.htmm/2003-6). These data resources are accessible through new digital library collections (see the Digimorph site noted above or the National Science Digital Library Kinematic Models for Design Digital Library [K-MODDL] at http://kmoddl.library.cornell.edu.