

Making Genetics Easy to Understand

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The Human Genome Project and the subsequent explosion of genomic information are transforming our knowledge of how organisms function and how genes and the environment interact. These insights have led to advances in personalized medicine, stem cell treatments, and genetic testing. Students, teachers, and the public must be prepared to make informed decisions about participation in genomics research, genome-related health care, use of genetically modified agricultural products, and public funding for stem cell research. Education has been identified as a crosscutting element that is critical to achieving the potential of genomics research (1).

To address this need for genomic literacy, we have developed two related Web sites. Learn.Genetics (see figure, right, from <http://learn.genetics.utah.edu/>) provides educational materials that currently cover 15 topic areas ranging from DNA to epigenetics. Classroom activities designed to support and extend these materials, as well as other resources for educators, are available on Teach.Genetics (<http://teach.genetics.utah.edu/>).

Our goal in developing these Web sites has been to make genetics and genomics easy for everyone to understand. The grants and contracts funding the sites have supported development of curriculum-supplement materials for grades 5 through 12 that address the National Science Education Standards (2) and gaps in standards-related, free, online, multimedia educational materials.

Web-site and in-person feedback indicate that the materials are used by a much broader audience. Students from middle school through

graduate school use the site to better understand content their instructors present, to assist in completing assignments, and to explore science independently. Higher-education faculty use the materials for courses ranging from introductory biology to professional preparation in education and nursing.

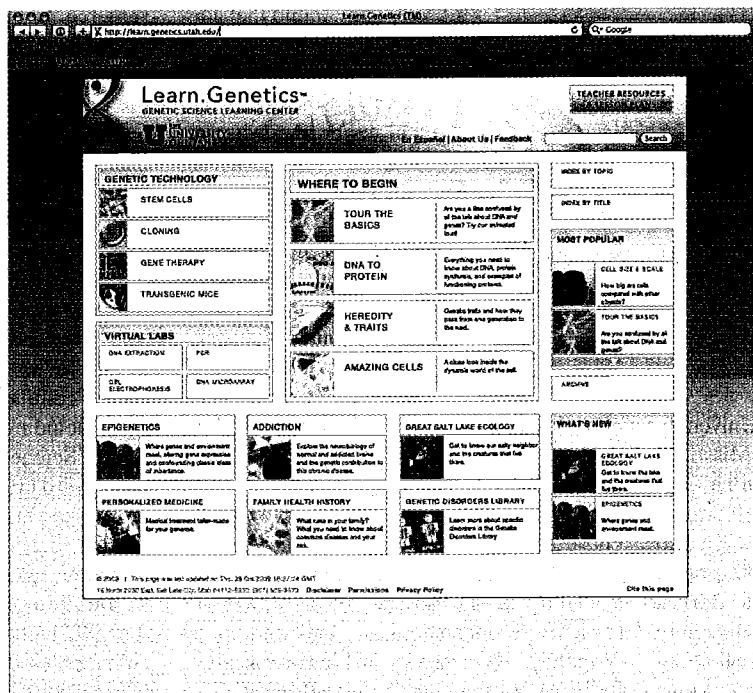
Animations presenting science concepts in an accessible and engaging way attract members of the general public, which leads

An integrated pair of Web sites for students and teachers supports genetics and genomics education worldwide.

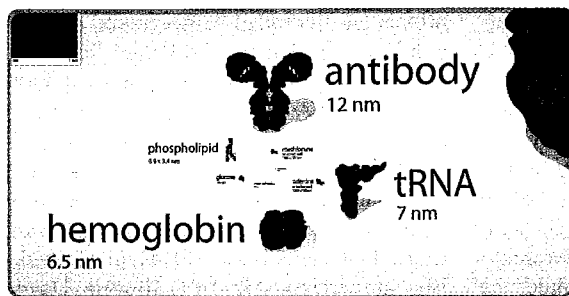
to “viral” dissemination through link-sharing Web sites and blogs. Although this type of dissemination is unpredictable, both our “Mouse party” and “Cell size and scale” (see figure below) interactive animations have spread this way, engendering discussions about science in over 30 languages around the world. “The new science of addiction: Genetics and the brain” module has received the most unanticipated use; it has been incorporated into police officer training and addiction treatment in several countries.

We use a participatory design approach to developing our materials, involving teachers and scientists along with the science educators, instructional designers, science writers, teacher professional developers, scientists, multimedia designers, Web developers, and evaluators that comprise our team. Our method emerged from extensive work with teachers in professional development programs and capitalized on teachers’ real-world expertise in successful teaching approaches, knowledge of engaging topics and materials, knowledge of the gaps in available online materials, and familiarity with the state science education standards guiding curricula. It also draws on scientists’ depth of expertise in their fields. Involving the center’s entire team builds understanding of the content and learning objectives and enables each to contribute his or her perspective and expertise to the process—from writing, visualization, production, classroom evaluation, and teacher professional development.

Our development process for a module begins with a summer workshop, advertised to teachers through our e-mail list. An online application enables us to select an outstanding group of 12 to 18 grade-appropriate teachers who represent a diversity of



Learn.Genetics. The site provides educational materials on 15 topic areas, ranging from DNA to epigenetics.



Cell size and scale. This interactive animation allows users to zoom from a coffee bean down to a carbon atom, comparing the relative sizes of representative cells, microorganisms, organelles and molecules along the way.

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teaching experience, student populations, and locales; about 5 to 10% of applicants are accepted. Participants receive travel expenses and a stipend.

A typical 4½-day summer workshop begins with talks by scientists and discussions of scientific articles, from which participants distill important concepts for their students. The teachers and our staff work together to define the “big ideas” that emerge from these concepts, around which the module will be organized. Small groups of teachers then develop each big idea, drafting online and classroom learning experiences designed to assist students in learning. The workshops offer a rare opportunity for teachers to develop creative ideas for curriculum materials that will be used worldwide, to interact with scientists, to update their content knowledge, and to work with other teachers from across the country. A glimpse into one summer workshop can be seen at <http://learn.genetics.utah.edu/content/epigenetics/credits/>. In it, teachers describe ideas that became the *Insights From Identical Twins* movie and “Gene control” interactive animation on Learn.Genetics and the “DNA and histone model” activity on Teach.Genetics.

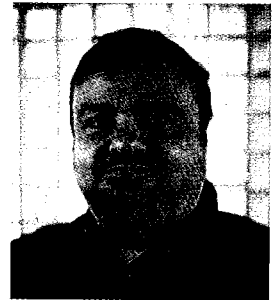
After the summer workshop, our team works with the materials the teachers drafted. Ideas may be combined, modified, expanded or contracted, as we plan a module that addresses the big ideas while fitting the anticipated cost within the available budget.

Our materials evolve each year as we learn from past modules and feedback obtained via classroom testing, teacher workshops, and Web-site feedback. At present, key module concepts are addressed in animated and interactive activities, because these appeal to the broadest range of learners. Narration allows users to concentrate on the animation and leads to deeper learning (3); text is available for those who are hearing-impaired or in computer labs lacking headphones. “Learn More” pages provide additional information for those interested in exploring beyond the basics. All pages are designed following standard Web usability guidelines (4), including meaningful visuals and text that is clear, concise, and easily scanned.

Good instruction addresses multiple learning styles, such as visual, auditory, and kinesthetic (5, 6). Therefore, our modules include non-computer-based classroom materials designed to support, extend, and assess online learning. For example, the somatic cell nuclear transfer (SCNT) technique utilized in the “Click and clone” interactive animation is mirrored in the



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Kevin Pompei is the GSLC associate director and leads the center's educational material development team. He has served as CEO of two software companies and has extensive experience in software and Web design, Web architecture, and database development, as well as managing teams of diverse technology professionals. He is working on a graduate degree in Educational Psychology with a focus on Instructional Design and Educational Technology.

paper-based “Let’s clone a mouse, mouse, mouse” activity. We suggest using the latter as an assessment for the online activity, asking students to use the mouse and petri dish paper cut-outs to create a poster describing the SCNT technique, without giving them the instructions. Additionally, worksheets are provided for many other animations to guide students’ learning.

An entire module comprises 2 to 10 hours of instruction. However, in designing our materials, we recognize that many teachers do not use a curriculum supplement module in its entirety (7). They select materials that address the science standards they are required to teach, are appropriate for their students’ level, and fit their instructional designs (7). For example, in the “Amazing cells” module, a seventh-grade teacher might only use “Inside a cell” and “Cell size and scale.” A high-school biology teacher might use these activities plus “Build-a-membrane,” “Coffee to carbon,” and “The fight-or-flight response.” To address multiple grade levels and teachers’ differing use of the curricula, each animation and classroom activity focuses on a single main learning objective, making it easier for teachers to incorporate the materials into their lessons.

As our team produces a module, they consult the scientists who participated in the summer workshop and others for additional information and to verify scientific accuracy. Currently, module production also includes development of valid and reliable assessment instruments, used in classroom field tests and later added to the resource materials on Teach.Genetics. A medium-sized module, such as “Epigenetics,” takes 3 to 4 months to produce.

Once a module is produced, it is tested in the classroom with students and teachers who were not involved in the development process. Students complete knowledge assessments before, after, and 2 weeks after studying a module. Teachers receive a stipend for their participation and feedback.

We have begun expanding beyond genetics with our “Amazing cells” and “Great Salt Lake ecology” modules. We hope to develop additional materials in the areas of life science and health and other scientific fields.

The Web has become the primary information source for individuals with access to the Internet. Online educational materials thus have the ability to affect science literacy, preparing individuals to participate in the workforce, as well as to become informed health-care consumers and citizens of the 21st century.

References and Notes

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8. Supported by NIH (National Center for Research Resources, National Institute on Drug Abuse, and National Human Genome Research Institute), Howard Hughes Medical Institute, March of Dimes, Health Resources Service Administration, R. Harold Burton Foundation, Sorenson Molecular Genealogy Foundation, Utah Department of Health, Great Salt Lake Institute at Westminster College, Children’s Tumor Foundation, and University of Utah. With thanks to the entire Genetic Science Learning Center team.

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