Universal Design in Science Learning

An overview of how universal design and technology can advance science for all

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Creating inquiry- and standards-based science curricula that meet wide-ranging learner needs and preferences requires strategic planning and organization. The common practice of retrofitting or modifying existing instructional and curriculum materials to accommodate individual learner needs too often overshadows the concept of designing universal learning experiences, which aim to minimize the need for accommodations and modifications.

Universal design is a framework for integrating flexible, usable, and accessible teaching and learning technologies with inquiry- and standards-based science curricula. This article presents an overview of how universal design and technology can advance science for all and provides scenarios of universal design in practice.

Inquiry with universal design

In the universal design framework, physical, social, and learning environments are created so that learner diversity—including cultural, socioeconomic, ethnic background, gender, and ability level—promotes powerful possibilities for teaching and learning. The implementation of universal design goes beyond programming of accommodations and modifications for individual learners. Because the aim of universal design is to make educational environments seamlessly and inherently functional for the widest number of learners, the need for individualization is minimized. The universal design framework guides the selection of flexible, usable, and accessible tools and surroundings, the construction of collaborative and interactive learning opportunities, and the development of learner-centered and constructivist curriculum (Figure 1, p. 35).

The National Science Education Standards call for teaching science as inquiry (NRC 1996), and research indicates that engaging in scientific inquiry increases student achievement in later courses and projects (Linn and Hsi 2000). The nature and implementation of inquiry-based curricula, however, often overlook the needs and preferences of diverse and varied learners.

Universal design guides the integration of inquiry with teaching methods and learning technologies that support the learning needs and preferences of the widest number of students (Curry 2003). Flexible, usable, and accessible content media, instructional technologies, and laboratory and field equipment include customizable and adaptive features, enabling almost all learners to participate in the same rigorous, progressive, and thoughtful curriculum.

Accessible content media

Content media are the means by which information is represented and communicated to learners via curriculum resources, including text, video, CD-ROM, and the internet. When identifying and selecting content media, learner accessibility and usability are paramount. To make content media accessible and usable by the widest possible number of learners, teachers should consider the following tools.

Digital text

Text is the most common medium for conveying curriculum content. In its traditional format, however, text is static on a printed page, which can hinder learners with print disabilities and English language learners.

The foundation of content media in accessible and usable format is electronically available, or digital, text. Digital text is malleable, meaning that it can be presented in multiple styles, and transformable, meaning that it can be converted and presented as computer-synthesized speech or even Braille (Rose and Meyer 2002). Furthermore, digital text is transferable—it can be moved from one application to another. Because digital text is inherently malleable, transformable, and transferable, learners have multiple options for customizing the appearance and format of digital content to meet their individual needs and preferences.

Digital curriculum materials for science are available through internet-based digital libraries (see "On the web" at the end of this article). Also, in response to the National Instructional Materials Accessibility Standard (NIMAS), publishers will soon provide textbooks and curriculum materials in standardized and inherently accessible and digital versions, which will simplify the conversion of text to alternate formats, such as Braille or audio. NIMAS is a new provision of the Individuals with Disabilities Education Improvement Act of 2004 (CAST 2006).

Accessible video

Video can be a powerful medium for conveying scientific knowledge and concepts to learners. Traditional video, however, lacks universal design features that promote accessibility and usability by diverse learners. Universal design of video includes captioning, which is a series of words superimposed on the television or motion picture frame that communicate dialogue, and audio description, which is a descriptive narration of visual elements of the video (see "On the web").

Although captioning and audio description may be associated with meeting the needs of learners who are hearing- or visually-impaired, respectively, these technologies have broad applications for all learners. Both captioning and audio description convey the content and meaning of the video in additional formats, meaning that all learners have improved access and increased opportunity to receive and process the information.

Accessible software applications

CD-ROM products can simulate experiential scientific content that might otherwise be unattainable for learners, such as interactive and guided investigative explorations of DNA, ecosystems, genetics, and the human body. Through a combination of hypermedia and multimedia, dynamic displays, and opportunities for manipulating the software, CD products can extend and expand student understanding of the content and concepts of the curriculum.

The design of software programs, however, can promote or inhibit student learning, depending on the attention given to accessibility and usability. Features such as the layout and organization of the interface, keyboard access, and intuitive functionality all contribute to users' abilities both to control effectively and learn from the product (see "On the web").

Accessible websites

In the fall of 2003, nearly 100% of American public schools had access to the internet (NCES 2005). Although school connectivity factors vary—including type of connection, school and instructional room access, computer hardware and software, and technical support—the internet is increasingly being used as a teaching and learning tool (Netday 2004). The internet is critically important to teaching and learning science, a content area that is continually evolving. Common uses include conducting inquiry-based research via search engines, participating in virtual labs and simulations, reading online journals (e.g., weblogs), developing classroom websites (e.g., wikis, which are websites where users can add and edit content), and communicating between and among learners, teachers, and the outside community (e.g., experts in the field of science and medicine).

Although the internet has had a dynamic influence on both available content and the process of learning science, it is not always scrutinized for accessibility and usability. Accessible websites incorporate features of universal design, such as easy-to-read fonts, clear and simple language, intuitive navigation, and a consistent and organized layout of information (see "On the web").

Learner-centered instructional technologies

Instructional technologies are the tools, models, and demonstration equipment that teachers use to convey scientific concepts, ideas, or principles. In the universal design framework, technologies are selected for their potential to contribute to instruction that supports multiple learning modalities, including visual, auditory, kinesthetic, and tactile. The more modalities a teacher aims to stimulate during science instruction, the greater the opportunity for diverse learners to receive and process the information, relate it to their own experiences, make connections to prior understandings, and construct new knowledge. Technology contributes several options that support multiple modality instruction. Examples of such technology include visual mapping software, presentation software, and electronic and interactive whiteboards.

Visual mapping software integrates several instructional strategies, including organizing, brainstorming, comparing and contrasting, classifying, and summarizing. Visual maps have been described as "graphically displayed thinking processes" (Hyerle 1996) and have been promoted by school-based research (Brabec, Fisher, and Pitler 2004; Singer 2004; Strangman, Hall, and Meyer 2003). Contemporary software programs allow maps to be an integration of digital text, color, symbols, images, digital photos, audio, and hyperlinks. Additionally, specific programs allow maps to be viewed simultaneously in both picture (diagram) and linear outline (text) views.

With presentation software, teachers can customize the content of their instruction in electronic visual displays or slideshows. By effectively integrating color, digital text, images, and sequence and navigation, teachers can create simple yet dynamic presentations that both supplement and extend traditional instruction.

A variety of electronic and interactive whiteboard products are available that convert a standard or specialized whiteboard into a dynamic display device via communication with a connected computer. Using electronic markers, a teacher can write over any image being projected on the whiteboard from the computer. Moreover, whiteboard notes can be captured on the computer in real-time and color, saved, printed, posted on a class website, and inserted into curriculum materials.

These technologies also turn a touch to the whiteboard into mouse clicks, allowing a teacher to control the computer from the focus of instruction, rather than from behind a keyboard. A final noteworthy feature of electronic and interactive whiteboards is that they allow video recordings of instructional events (e.g., steps to solving math problems or balancing chemical equations), which can be saved and later accessed by students for review and reinforcement.

Accessible laboratory and field equipment

Some of the best inquiry-based learning opportunities in science authentically simulate lab and field investigations undertaken by active researchers and scientists. Universal design guides the identification and selection of tools (e.g., meters, probes, data collection and display devices) that ensure participation of almost all learners while minimizing the need for individual accommodations. These same tools incorporate multimodal representations of the information they are designed to deliver, increasing the opportunity for diverse learners to capture accurately the evidence and data that they are collecting.

Computer-controlled laboratory equipment is an example of a universal design tool. A sensor—or other interface hardware, such as a temperature probe—is connected to a computer or handheld device, and specialized software controls the timing of measurements and the recording and display of data throughout the experiment. Because the data are recorded and displayed digitally, access can be customized for diverse learner needs and preferences (e.g., display appearance, speech output). Furthermore, most contemporary computer-controlled lab software products are compatible with both Macintosh and Windows operating systems, enabling students to use the systems' built-in accessibility features (see "On the web") in the process of interpreting and manipulating data.

Additional examples of universal design tools for laboratory and field work include

- meters and probes with audible readout (e.g., enabling a light probe to emit a tone that increases in pitch proportionally to changes in light intensity);
- talking thermometers, balances, and calculators;
- laboratory glassware with raised numbers;
- electronic note takers and portable word processors;
- digital voice recorders;
- adequate lighting and magnification;
- digital cameras; and
- MP3 players.

Two scenarios of universal design

Field trip preparations

[National Science Education Content Standard D for Grades 9–12: All students should develop an understanding of energy in the Earth system (NRC 1996, p.187).]

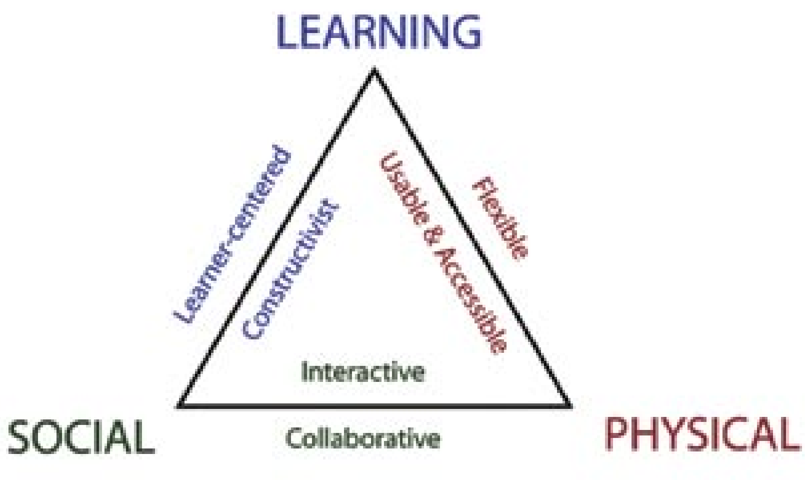
Teacher Fernando Torres is preparing his students for a field investigation of a local park, which consists of approximately 1.0 km^2 of field and forest, in addition to a small stream and swamp. The setting provides manageable sites and a natural laboratory for examining species diversity and soil types in different habitats, as well as a convenient location for observing global climate change over time. These are topics that his students have studied over the previous semester.

After sharing the goals and objectives of the field investigation, Mr. Torres invites students to contribute their own essential questions. He swiftly captures students' contributions using visual mapping software and an overhead projector that displays the computer screen. The following is a sampling of student-generated essential questions:

- How does the soil look different/feel different/smell different between the fields and the swamp?
- How many different kinds of plants can we find?
- How does the vegetation differ between the fields and the swamp?

FIGURE 1

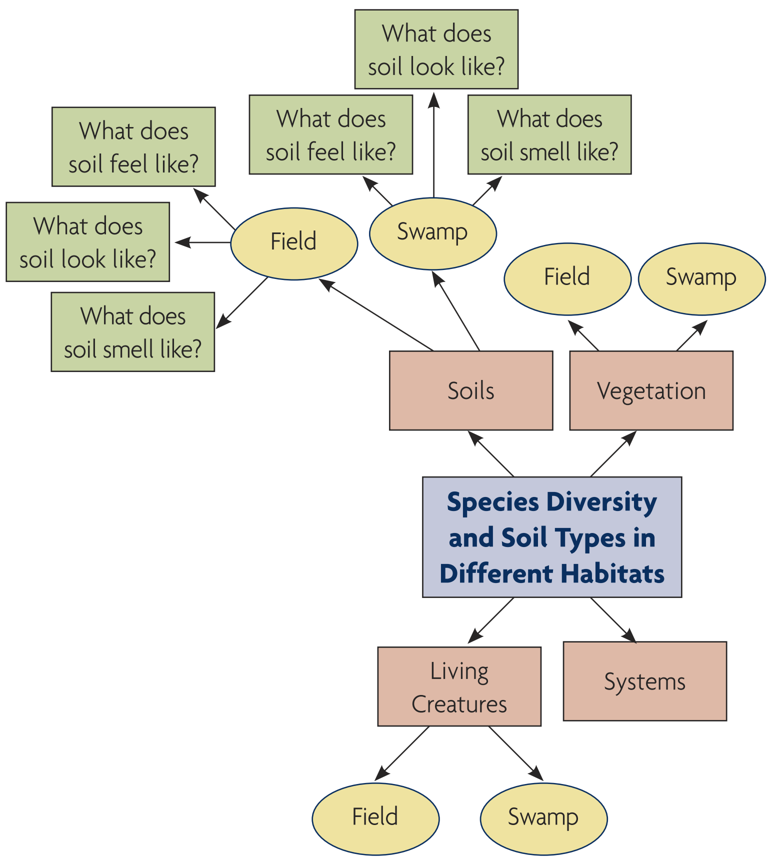
The physical, social, and learning environments of universal design.



(Developed by Cynthia Curry; Permission to reprint provided by ALLtech © 2006.)

FIGURE 2

Emerging class visual map.



Universal design provides a framework for science educators to ensure that teaching and learning opportunities are not only standards-based, but inherently flexible, accessible, and usable.

- What are the differences in the breeze and temperature at these two places?
- What kinds of birds are using the fields? The swamp?
- What are the birds eating?

Using the features of the visual mapping program, students then assist Mr. Torres in arranging the questions by categories, such as soils, vegetation, systems, and living creatures (Figure 2, p. 35). After the map is complete, he posts it on the class website, where students can access and customize it for their own needs and uses. Several students, for example, create a hyperlink to the map within their electronic field journals.

Another preparatory activity that Mr. Torres develops is a collaborative WebQuest *(http://webquest.sdsu.edu)* or inquiry-based online research module, customized to simulate the field investigation they are about to conduct. The WebQuest incorporates aerial photographs of the site, as well as plant species, soil types, and wildlife that might be found there. For supplemental resources to complete the WebQuest, Mr. Torres refers students to the NASA Earth science website *(http://science.hq.nasa.gov/education/index.html),* as well as the Digital Library for Earth System Education *(www.DLESE.org)*.

Prompted by the WebQuest, students hypothesize what they expect to find during their investigation. Students construct models of soil structure units out of clay, fun foam, or plastic; they also create three-dimensional models of soil profiles with each horizon emphasized by a different tactile material such as a piece of string or a pipe cleaner.

During the class session just prior to the trip, Mr. Torres reviews with students the expectations and tasks for the day, a variety of strategies and tools for collecting data, and diverse methods for examining the data upon return to the classroom. Digital recorders, portable word processors, and digital cameras will be available for students to use to produce images and audio recordings to add to their visual maps and electronic field journals.

Constructing the motion of objects

[National Science Education Content Standard B for Grades 9–12: All students should develop an understanding of motions and forces; and National Science Education Content (NRC 1996, p. 176). Standard G for Grades 9–12: All students should develop an understanding of science as a human endeavor (p. 200).]

Teacher Salma Khan is preparing her students for an inquiry-based study of Newton's laws of motion by constructing necessary background knowledge. By previously engaging students in a study of kinematics—the science of describing the motion of objects using words, diagrams, numbers, graphs, and equations—she effectively enables students to create mental models that describe and explain the motion of real objects in the world around them. Students demonstrate their mental models using multiple means, such as:

- Vehicles built from LEGO blocks;
- Virtual animations from the website of *The Physics Classroom (www.physicsclassroom.com)*;
- Concept maps constructed via visual mapping software; and
- Charts and graphs.

These demonstrations inform Ms. Khan's assessment that her students are relying upon accurate mental models of the concepts necessary for an authentic and inquiry-based examination of Newton's laws, such as motion, force, and acceleration.

Ms. Khan introduces Newton's laws by first acquainting students with the scientist himself. She has learned from experience that by personalizing science, or facilitating learners' appreciation that science is a human endeavor, students connect more meaningfully with content, sometimes even identifying with and relating to the characteristics of the scientists (Schopf 2005).

Using presentation software and an interactive whiteboard, Ms. Khan provides a brief biography of Isaac Newton, not only highlighting his contributions to our understanding of numerous physical phenomena, but describing more intimate details of his life, beginning with the death of his father before he was born and being separated from his mother at a young age. The presentation integrates text, color, photos, images, quotations, and hyperlinks to relevant websites, such as *The Newton Project (www.newtonproject.ic.ac.uk)*.

The inquiry of Newton's laws is presented as a series of investigations and experiments. Ms. Khan uses flexible grouping, a method for strategically grouping learners according to those who would benefit from the same kinds of instruction and support. Throughout the unit, she also utilizes peer support strategies to extend her practice of differentiation.

One of the first collaborative investigations begins when Ms. Khan creates a video recording of a toy car accelerating down a ramp. The video is then imported into a data collection program on the class computer. In turns, student groups use the program to visually track the position of the car, frame by frame, and calculate velocity and acceleration. The program allows students to replay the video with simultaneous data and graph display, providing multiple opportunities for individual learners to conceptualize the relationship between velocity and acceleration.

Framework for the future

Science curricula featuring inquiry must be informed by tools, strategies, and methods designed to meet the needs and preferences of diverse learners. Universal design provides a framework for science educators to ensure that teaching and learning opportunities are not only standards-based, but inherently flexible, accessible, and usable. And, as technology continues to evolve and becomes increasingly more dynamic—and affordable—the principles of universal design will become more critical to advancing science for all. ■

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References

Brabec, K., K. Fisher, and H. Pitler. 2004. Building better instruction: How technology supports nine research-proven instructional strategies. *Learning & Leading with Technology* 31(5): 6–11.

Center for Applied Special Technology (CAST). 2006. NIMAS technical specification. *http://nimas.cast.org/about/technical/index.html*.

Curry, C. 2003. Universal design: Accessibility for all learners. *Educational Leadership* 61(2): 55–60.

Hyerle, D. 1996. *Visual tools for constructing knowledge*. Alexandria, VA: Association for Supervision and Curriculum Development.

Linn, M.C., and S. Hsi. 2000. *Computers, teachers, peers: Science learning partners*. Mahwah, NJ: Lawrence Erlbaum Associates.

National Center for Education Statistics (NCES). 2005. Internet access in U.S. public schools and classrooms: 1994–2003. *http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2005015*.

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academy Press.

Netday. 2004. Insights and ideas of teachers on technology. *www.netday.org/sud4teachers_2004_report.htm*.

Rose, D., and A. Meyer. 2002. Teaching every student in the digital age: Universal design for learning. *www.cast.org/teachingeverystudent/ideas/tes*.

Schopf, K. 2005. Kekule's dream and Bunsen's burner. *The Science Teacher* 72(5): 30–33.

Singer, B. 2004. Leveling the playing field for all students. In *Student successes with thinking maps*, ed. David Hyerle, pp. 29–38. Thousand Oaks, CA: Corwin Press.

Strangman, N., T. Hall, and A. Meyer. 2003. *Graphic organizers with UDL*. Wakefield, MA: National Center on Accessing the General Curriculum. *www.cast.org/publications/ncac/ncac_goudl.html*.

On the web

Web-based digital libraries

BiosciEdNet: *www.biosciednet.org*

National Science Digital Library: *http://nsdl.org*

Gender and Science Digital Library: *http://eecgsdl.edc.org/index.php*

Digital Library for Earth System Education: *www.dlese.org*

Accessible video

Captioned Media Program: *www.cfv.org*

National Center for Accessible Media (NCAM): *http://ncam.wgbh.org*

Accessible software

Making Educational Software Accessible: *http://ncam.wgbh.org/cdrom/guideline2000*

Accessible websites

Web Accessibility Initiative: *www.w3.org/WAI*

Built-in accessibility of computer operating systems

Apple Accessibility: *www.apple.com/accessibility*

Microsoft Accessibility: *www.microsoft.com/enable*