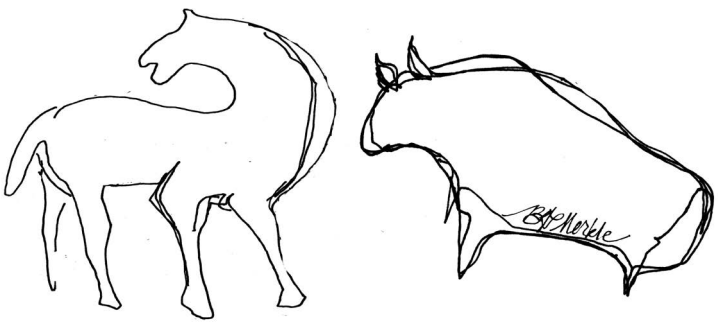
PERSPECTIVE

Drawn to science

Teachers do not need training in the arts to create useful drawing experiences for science students, says **Bethann Garramon Merkle**.

JEROD ANDREW MERKLE

People think in images. Indeed, archaeological records show that drawing was the first means of visual representation (see go.nature.com/2qfxe7h). The lines and dots of the earliest rock art — some 64,000 years old — indicate conceptual, creative thinking. Cave engravings in France depict well-proportioned, figurative observations of wildlife made some 26,000–38,000 years ago (below). Today, images remain powerful tools for learning, documenting and facilitating thinking. Taking notes by hand[1], or even doodling, results in better retention of information and higher intellectual engagement with the material than does typing on a laptop. Fundamentally, creativity is a whole-brain process, and artists and scientists use the same parts of their brains to do complex, creative tasks[2]. Ensuring that students understand the value of drawing can help motivate them to draw.



Sketches documenting prehistoric rock carvings from the Grotte de Pair-non-Pair in France indicate the use of perspective in prehistoric art.

When my colleagues try to integrate drawing into their laboratory and field courses, however, they frame their motives more matter-of-factly. For example, one biology-lab coordinator noticed that students mainly interact with specimens by photographing them. She suspected that students did not gain much from taking these photos, on the basis of their exam scores. Her hunch is substantiated by research indicating that analogue note-taking is more effective than using laptops[1], and that students score more highly on exam questions that correspond to topics for which drawing is required. To make students engage more fully with specimens, I worked with the lab coordinator to build drawing into the curriculum. But even without previous training in the arts, teachers can create productive drawing experiences for their students.

Drawing is a scientific tradition that has contemporary validity. Drawing has been an important tool throughout the history of science. Connecting students' coursework to this tradition encourages students to see drawing as a fundamental tool of science. In ancient Greece, for example, protoscientists such as Aristotle drew to help them understand animal anatomy. In Renaissance Italy, Leonardo da Vinci's drawing-based investigations of the erosive force of water predated fluid mechanics by several centuries. In the seventeenth century, Maria Sybilla Merian was the first to study and depict ecologically accurate insect life cycles (above right). Her illustrations definitively countered the prevailing belief in spontaneous generation.

By developing their drawing skills through practice in the classroom, students can contribute to this legacy as well as enrich their own scientific experiences.

Drawing skills can be learnt and taught. Students frequently object when asked to draw because they have little confidence in their abilities and limited training in the arts. Indeed, without adequate basic training, drawing can be a hurdle rather than a tool. However, drawing in science need not be about making great art; the emphasis can be on accuracy, enhanced observational skills and asking deeper questions. Furthermore, the basics of modern drawing are learnt, not inherited. For example, 3D drawing took about 400 years to develop and was not fully understood until the Renaissance. Fundamental skills, techniques and knowledge of different media, such as watercolour, pencil, and pen and ink, can be taught, applied and improved.

ROCK CARVINGS: BETHANN GARRAMON MERKLE; INSECT LIFE CYCLE: MARIA SYBILLA MERIAN

Maria Sybilla Merian's seventeenth-century study of the insects of Suriname and their life histories foreshadowed contemporary ecology.

Students' coursework should include training in basic drawing skills and an expectation that students will draw in every class. Teachers who lack the confidence to lead drawing instruction can collaborate with a colleague who has drawing skills or their institution's art faculty. Individuals and companies offer arts-related professional development and classroom-based instruction, including local, professional, science-focused artists. To find such artists in the United States, check the Guild of Natural Science Illustrators' membership list (gnsi.org); other countries have similar professional organizations.

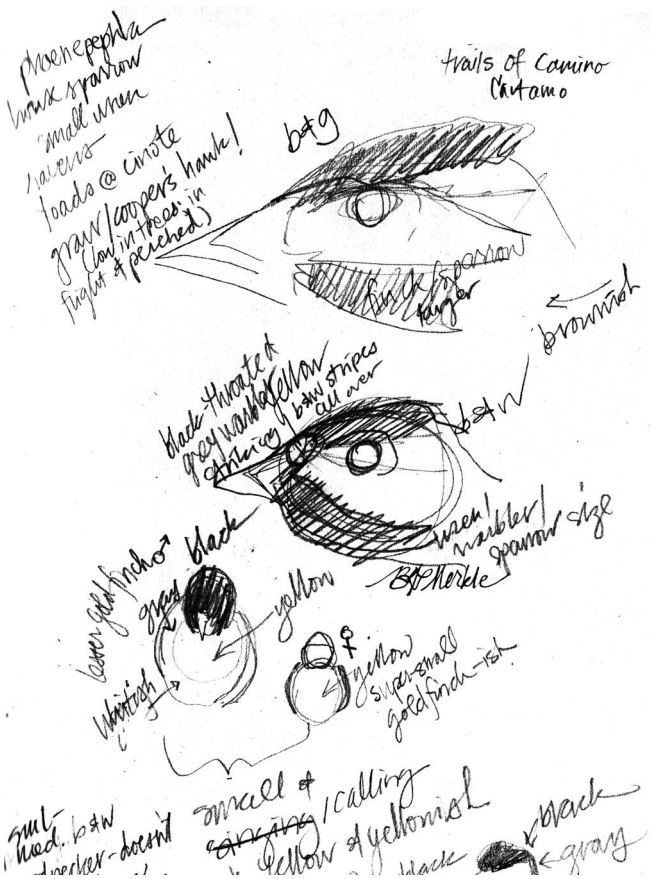
For resistant students, Charles Darwin offers a cautionary tale. Despite encouragement from his colleagues, Darwin refused to learn to draw and always regretted it. In his autobiography, he bemoaned the "irremediable evil" of his "incapacity to draw" and acknowledged that his notes were less useful than they could have been if he had made his own illustrations. Similarly, teachers need to commit to drawing as a demonstration of what they expect from their students. Consider, for example, drawing during lectures, sketching alongside students during dissections to point out features of interest, or even including rough sketches in lecture slides.

The way that drawings are assessed is crucial. As well as serving as a learning tool, drawing can be a powerful mechanism for both formal and informal assessment. In the project Picturing to Learn (www.picturingtolearn.org), drawings by students at Harvard University, the Massachusetts Institute of Technology, Duke University and other institutions were evaluated for the presence or absence of essential aspects of scientific systems and concepts. The drawing assignments and test questions "revealed misconceptions in a way that text does not", according to one participating professor. For example, asking students to draw a diagram explaining why the sky is blue forces them to demonstrate, beyond memorized equations and keywords, what they do or do not understand.

The type of drawing matters less than the fact that students are drawing. Teachers could ask for a highly polished illustration of a leaf, sketches of a few circles indicating locations at a research site, or a diagram of genetic relationships in a phylogenetic tree. The context will determine how representational or abstract a drawing needs to be. For example, to represent a wolf, a box containing the word 'wolf', a stick drawing of a wolf, a caricature, or a more photorealistic picture of a wolf might be appropriate, depending on the assignment[3].

Importantly, teachers should evaluate the content and accuracy of such sketches, not their artistry. For example, the sketches below depict birds that I found difficult to identify in the field. Quick and rough, these sketches captured fairly detailed information in the line work and accompanying notes that proved sufficient for looking up and correctly identifying the species later: it was the northern phainopepla (*Phainopepla nitens*). Sketching in this way can enhance learning, observation and drawing skills. For example, these drawings are stronger artistically than the bird sketches I made a decade earlier when I first began to use drawing to understand

BETHANN GARRAMON MERKLE



Bird sketches by Bethann Garramon Merkle; their detail and accuracy enabled Merkle to identify the species later, when she added the species name and further notes.

JEAN LIEPPERT POLFUS

Dene First Nation hunters and elders annotated a researcher's drawing to combine traditional ecological knowledge with a genetic study of caribou biodiversity.

ecology. Combining both practice and training can lead to enhanced artistic skill.

Science teachers should get their students to use drawing as part of informal activities as often as possible. The idea is to gradually build up to low-stakes, graded assessments before ultimately using the students' drawings in high-stakes assessments.

As well as supporting learning outcomes, research indicates that drawing (even without training) can enhance visual-thinking skills, creativity and problem-solving, and can improve science-communication efforts. There is even evidence that collaboration between scientists and artists can result in better science. For example, successful caribou management and conservation in Canada depends on strong relationships between researchers and indigenous First Nations communities. These relationships are often tenuous. Jean Polfus, an artist and ecologist at Trent University in Ontario, used drawings to document Dene First Nation traditional ecological knowledge about caribou phenotypes. Local hunters and elders annotated the drawings (above), which Polfus then revised for them to review. Through this iterative drawing process, elders overcame their reluctance to participate in the research. Polfus was able to incorporate traditional ecological knowledge in genetic analyses of scat samples collected by Dene hunters. Ultimately, these genetic analyses accorded with the phenotypes recognized by tribal elders. Drawings were at the root of this collaborative process[4].

In similar ways, researchers, instructors and students can use drawing to learn course content and enhance scientific thinking. Sketching, assessing and revising drawings will provide practice in a skill set that has been central to the practice and communication of science for centuries. ■

Bethann Garramon Merkle *is an illustrator and researcher at the University of Wyoming in Laramie. She has consulted on the implementation of incorporating drawing as a teaching method in science classrooms throughout North America.*
e-mail: bmerkle@uwyo.edu.

1. Mueller, P. A. & Oppenheimer, D. M. *Psychol. Sci.* **25**, 1159–1168 (2014).
2. Andreasen, N. C. & Ramchandran, K. *Dialogues Clin. Neurosci.* **14**, 49–54 (2012).
3. Quillin, K. & Thomas, S. *CBE Life Sci. Educat.* **14**, 1–15 (2015).
4. Polfus, J. L. *et al. Ecol. Society* **22**, 4 (2017).