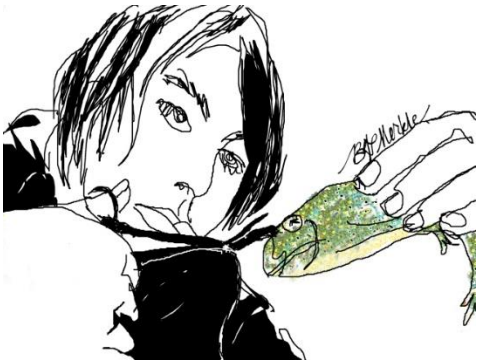
Suggestions for integrating drawing into university-level biology courses

I'm collaborating with the coordinator of a series of undergraduate Animal Biology labs this semester. She is interested in integrating drawing more fully and effectively into the work that instructors and students do in those labs. Her motivation stems, at least in part, from noticing that photographing specimens appears to be the most common way students interact with specimens in these labs. And yet, based on low exam scores, students aren't getting much out of taking photos.



And so, we've been talking about how to utilize drawing as an active learning tool, as well as a self- and summative assessment strategy. Considerations include how to introduce drawing to TAs and students, and how to integrate it in myriad forms (phylogenetic trees, graphs, food web diagrams, specimen sketches, etc.) throughout lab activities, homework assignments, quizzes and exams.

We'll be doing a TA training session before the semester begins, to ensure the TAs have basic familiarity and comfort in sketching and to troubleshoot facilitating it with their students. As we planned all this, I realized that one thing I take for granted is my capacity to articulate how and why to utilize drawing in these ways.

And so, I offered to write up some text which she could copy or modify and distribute to TAs and students. What follows is what I've come up with. Feel free to utilize it, and if you do, ***please do*** let me know how it goes, if and how you adapted it, etc.

Please provide attribution/links for all material, even if you revise the text based on your own interpretation of the materials cited herein.

And again, I'd love to hear what you come up with!

Notes on drawing for science learning

Bethann Garramon Merkle, art-science integration specialist, www.commnatural.com
Sketching for Scientists™ & Drawn to Science™

Humans think in images. Our brains actually understand images faster, and remember images longer, than words [1]. Archaeological records indicate that drawing was the first visual representation method [2]. And history demonstrates that drawing has been an integral part of learning for centuries.

Petroglyphs in northwest Montana
(Credit: Bethann Garramon Merkle)

Even better, we know that drawing is an incredibly powerful tool for learning scientifically [3], and for helping us assess our own knowledge [4] and misconceptions about material we're studying [5]. We also know that keeping notes by hand [6] (even doodling! [7]) results in better retention of the information, higher intellectual engagement in the material, and therefore, better grades.

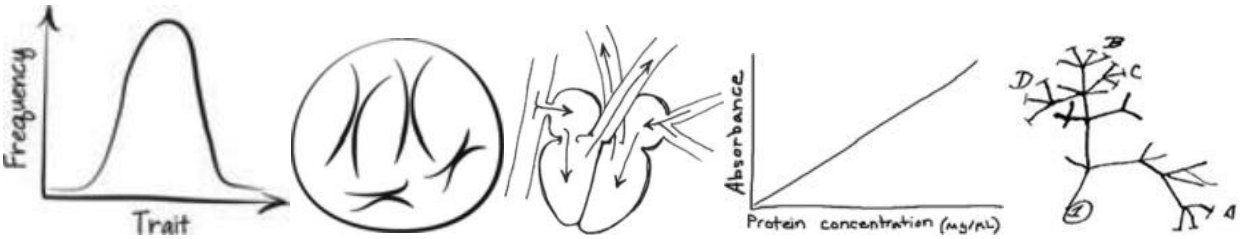
Drawing (even without training) can: aid learning & memorization [8], help clarify what you know [9], enhance research methodology [10], improve your experience with and performance on assessments [11], enhance your visual thinking skills [12], enhance creativity and problem solving [13], and enhance science communication efforts [14]. There is even evidence that collaboration between scientists and artists [15] may result in better science [16].

This is all pretty important, considering that a lot of the things that we do and use in our daily lives depend upon scientific knowledge. Whether you're sending a text, taking a photo, eating an apple in December, or using a hand sanitizer, you're tapping into the wealth of technology and information that has been derived through scientific study and experimentation.

Whether you pursue a career in science or just want to be sure your decisions are informed by facts, thinking scientifically and understanding science-related information has great value for you and society.

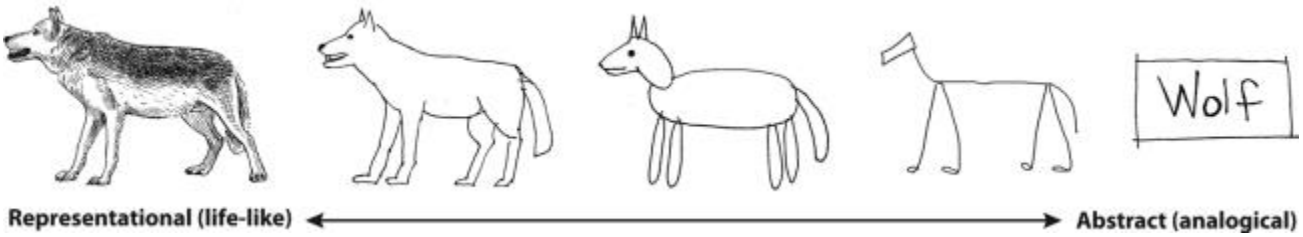
So, it is also important that you learn some of the skills associated with this way of thinking. And drawing is a significant one. For our purposes in this course, you might make a highly-polished illustration of a leaf, sketch out a few circles indicating locations at a research site, diagram

genetic relationships in a phylogenetic tree, or graph experimental results. All of these approaches count as drawing.



Examples of different types of drawings you may make in this class.
(Credit: K. Quillan & S. Thomas, Drawing-to-Learn Framework)

Indeed, in our class and in general, "drawings can vary to the degree in which they should be representational or abstract, depending on context. For example, a highly representational drawing of a wolf might be appropriate to a study of wolf behavior (where the stance and position of ears and tail is germane to the point), but a mere box with the word "wolf" might be appropriate in a food web or concept map" [17].



(Credit: K. Quillan & S. Thomas, Drawing-to-Learn Framework)

Think you can't draw? That's okay! *

Despite research demonstrating how effective drawing can be for learning and for assessment, a lot of people avoid this powerful visualization tool because they themselves don't have drawing training. However, the good news is that "We're not making great art; we're using rough sketches to note important things about our specimens," experiments, and observations [18]. We can and will aim for sketching skills that are useful for our discipline.

Happily, the way our minds learn to draw is similar to how we learn to speak [19]. Further, by the time we are toddlers, most of us have the cognitive and motor skills necessary to use a pencil and make marks. It could be argued that humans are actually born knowing how to draw [20]. And, as mentioned earlier, our collective ability to draw goes back even further, to prehistoric records made deep in caves.

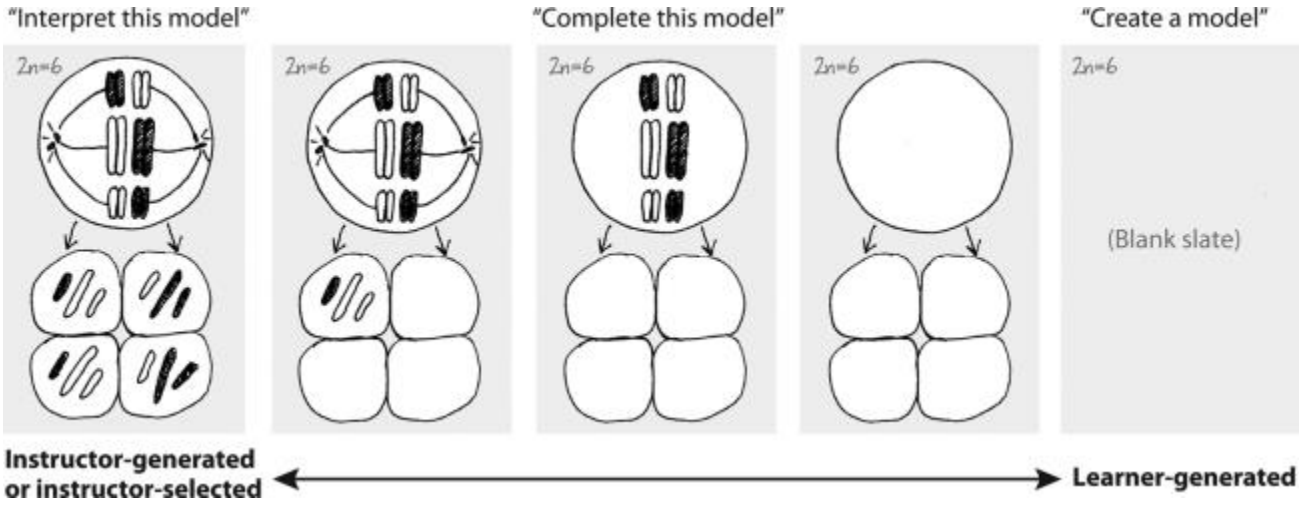
Better yet, drawing as we know it today isn't a magical gift. Three-dimensional drawing, for example, took about 400 years to develop [21], and it wasn't fully understood until the Italian

Renaissance. Modern drawing basics are learned, not inherited. Fundamental skills, techniques, and knowledge of different media (ex: watercolors, pencils, pen and ink) can be taught, practiced, and improved upon.

Child sketching a bison
(Credit: Bethann Garramon Merkle)

Thanks to a combination of your childhood aptitude and learning basic drawing techniques, anyone can learn to make sketches that are useful in learning and doing science.

This is why our coursework will include training in basic drawing skills and an expectation that you will draw in every class. You will receive feedback on the content and accuracy of your sketches, not the artistry of them, through exercises, including those spanning the spectrum shown below.

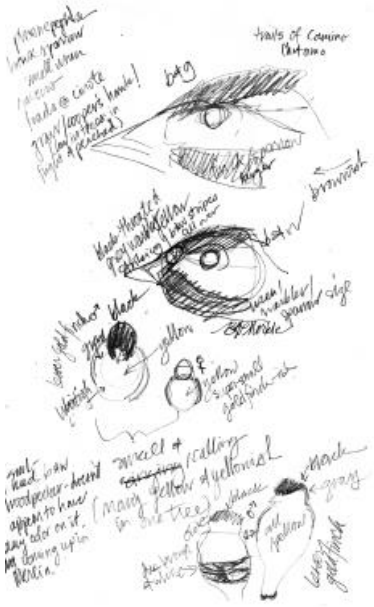


(Credit: K. Quillan and S. Thomas, Drawing-to-Learn Framework)

While repeatedly drawing from observations can help your drawing abilities improve in an aesthetic sense, our emphasis will be on using drawing as a tool and a learning process. For example, in the images below, the skull and feather may be visually appealing, but they aren't very useful for learning, studying, or demonstrating knowledge.

Sketches of bird skull and bird feather
(Credit: Bethann Garramon Merkle)

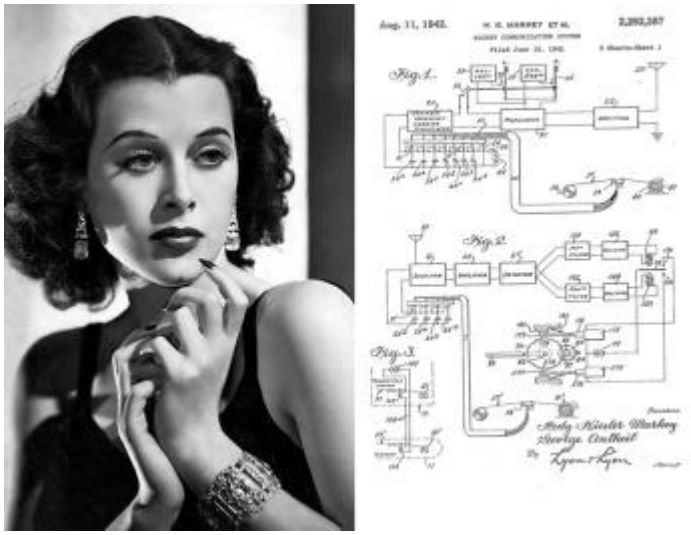
On the other hand, the second image is a set of field sketches of birds the sketcher found difficult to identify. While quick and rough, these sketches recorded lots of fairly detailed information, both in the line work and the accompanying notes. The information was sufficient to look up and correctly identify the species later. That's when the sketcher added in the name of the species and some additional notes for future reference.



Field sketches of an unfamiliar bird
(Credit: Bethann Garramon Merkle)

Together, we'll use drawing both to learn course content and to practice scientific thinking. By sketching, and then assessing and revising drawings in this way, we will together develop a skill set that has been central to the doing and discoveries of science for centuries [22].

And just like drawing isn't exclusive to artists, neither is innovation exclusive to established scientists. For example, a Hollywood actress during WWII invented a wireless communication system that underpins all our modern wireless technology [23]. She did it by paying attention, asking questions, and connecting ideas that others around her took for granted.



Actress Hedy Lamarr & her patent drawings of early wireless technology she invented (Credit: Wikimedia Commons)

"The ability to notice, question, and direct our thought processes" is called *metacognition*. Metagognitive thinking is essential to innovation, invention, and discovery. And, a wealth of research indicates drawing can help us think in this way [24], [25].

Indeed, "training the brain to draw, to engage with eye and hand, is to learn to be open to surprise, to perceive underlying structures and make unexpected connections and discoveries. In moving beyond automatic, superficial, and stereotyped responses and developing metacognitive skills like constructive perception, it is possible for those who draw to become deeper and more creative thinkers who are better equipped to solve problems across disciplines and make the leaps forward that advance all of us"[26].

RECOMMENDED READING

You and your students may find it useful to read the following recommended articles. In particular, you may all be engaged, inspired, and informed by *Field Notes on Science and Science.* The book is a collection of essays about keeping notes from scientists working in a range of disciplines from anthropology and geology to comparative anatomy. There is also a chapter by a scientific illustrator which provides numerous accessible and useful drawing tips.

RECOMMENDED READING FOR INSTRUCTORS

In addition to the introductory note above, you and your students may find it useful if you as an instructor read the following:

- **Biological Drawing: A Scientific Tool for Learning** – this article outlines a number of the introductory sketching techniques I teach in educator training sessions and student workshops. While the descriptions of the activities in this article differ somewhat from how I facilitate/suggest facilitating these techniques, the article nevertheless provides a valuable reference for educators seeking to inform their own efforts to introduce and facilitate drawing in the classroom. Citation: Dempsey, B.C. and B.J. Betz. 2001. Biological Drawing A Scientific Tool for Learning. *The American Biology Teacher*, 63(4):271-281. (https://goo.gl/6UK0qI)

- **Drawing-to-Learn: A Framework for Using Drawings to Promote Model-Based Reasoning in Biology:** A really valuable combo article which provides images you can use to decide what kind of drawing you want students to make, and then explain to the by visual examples how your expectations compare to other possibilities. Many of the figures in the text of the note above are from this article. The article is also a synthesis of literature and instructional strategies for integrating drawing into biology (including the many subdisciplines ranging from botany to molecular biology). The article provides both an orientation to the utility of drawing and the potential challenges of utilizing it in your classroom, as well as a tables with examples for how to actually facilitate and assess student drawings depending on specific course objectives. Citation: Quillin, K. and S. Thomas. 2015. Drawing-to-Learn: A Framework for Using Drawings to Promote Model-Based Reasoning in Biology. *CBE Life Science Education* 14:es2. (https://goo.gl/DD5Oty)

- **Drawing to Learn in Science:** a brief (2-pg) article detailing several reasons why/how to utilize drawing in science learning and instruction. Citation: Ainsworth, S. V. Prain, and R. Tytler. 2011. Drawing to Learn in Science. 333:1096-1097. (https://goo.gl/Y3RESa)

- **Drawn to Science: Exploring the Historical and Contemporary Synergies between Drawing, Creativity, and Science:** a 1-hour video recording of an invited seminar I gave to the University of Wyoming's Zoo/Phys department in 2016. (https://goo.gl/EaBmpp)

- **Opening the world through nature journaling: integrating art, science & language arts:** The brief introductory notes in this curriculum include rationale for integrating drawing, basic drawing instruction, and very importantly, examples of do/don't responses to use when commenting on student drawings. For example "Don't say, 'That is really pretty.' […] Do say, 'I see you have shown hairs on the stem. Details like that become important to botanists when identifying and studying plants.'" Citation: Laws, J.M., E. Breunig, E. Lygren, and C. Lopez. 2012. *Opening the world through nature journaling: integrating art, science & language arts, 2nd ed.* California Native Plant Society. (link to free download of curriculum: https://goo.gl/upzOjJ)

RECOMMENDED READING FOR STUDENTS

In addition to the introductory note above, you and your students may find it useful if they read the following:

- **A learning secret: don't take notes with a laptop:** *Scientific American* reports on research indicating that hand-written notes are more useful for students. Citation: May, C. 2014. A learning secret: don't take notes with a laptop. *Scientific American*; accessed online. (https://goo.gl/55NkNN)

- **Why scientists (even non-artists) should draw:** A brief article detailing numerous important applications for drawing in the study of the biological sciences. Citation: Merkle, B.G. 2015. Why Scientists (even non-artists) should draw. *Crastina.se*. (https://goo.gl/A8LqvB)

REFERENCES

[1] Fascinating study shows how to open a closed mind (https://goo.gl/Yl0cxr) and research cited (https://goo.gl/awhVOP) in "Fascinating study" article

[2] Art History Timeline (https://goo.gl/Uj8qsb) and Metropolitan Museum of Art Heilbrunn Timeline of Art History (https://goo.gl/hlTX7C)

[3] Drawing to Learn in Science (https://goo.gl/J26zDP)

[4] Drawing on Experience: How Domain Knowledge Is Reflected in Sketches of Scientific Structures and Processes (https://goo.gl/niF4Uq)

[5] www.picturingtolearn.org

[6] A learning secret: don't take notes with a laptop (https://goo.gl/rbtYS8) and research cited (https://goo.gl/ciMhMw) in "A learning secret."

[7] What does doodling do? (https://goo.gl/7PKjKj)

[8] Drawing to Learn in Science (https://goo.gl/RDHTQJ)

[9] http://www.drawntoscience.org/researchers/index.html

[10] Sandra Knapp review of *Field Notes on Science and Nature* (https://goo.gl/2nygpd)

[11] www.picturingtolearn.org

[12] Drawing on the right side of the brain: A voxel-based morphometry analysis of observational drawing (https://goo.gl/wZCXih)
[13] Selected Findings from the Kennedy Arts Center's Arts In Education Research Study: An Impact Evaluation of Arts-Integrated Instruction Through the Changing Education Through the Arts (CETA) Program (https://goo.gl/CDIjZc)
[14] Are we hardwired to doodle? (https://goo.gl/gN3Poh)
[15] Why art and science? (https://goo.gl/bnGLYc)
[16] Why scientists should care about art (https://goo.gl/Hyjzwx)
[17] Drawing-to-Learn: A Framework for Using Drawings to Promote Model-Based Reasoning in Biology (https://goo.gl/BJIEOs)
[18] *Dr. Stephen B. Heard, from comments on blog post (https://goo.gl/Nalt9Y). This post has been revised to reflect the suggestions he made.
[19] Explaining 'I Can't Draw': Parallels between the Structure and Development of Language and Drawing (https://goo.gl/NvsGGF)
[20] http://www.historyofdrawing.com/History_of_Drawing/Prologue.html
[21] The rise of the Renaissance perspective (https://goo.gl/QupfyL)
[22] A Memorial to Hollywood Star Hedy Lamarr, a Founding Mother of Modern Tech (https://goo.gl/WQLyNK)
[23] Why scientists (even non-artists) should draw (https://goo.gl/ztZHF2)
[24] The genesis of errors in drawing (https://goo.gl/zXTSKt)
[25] The benefits of sketching for knowledge management (https://goo.gl/VOsto5)
[26] The Man behind the Curtain: What Cognitive Science Reveals about Drawing (https://goo.gl/ibkRMH)