Visual Literacy in Science

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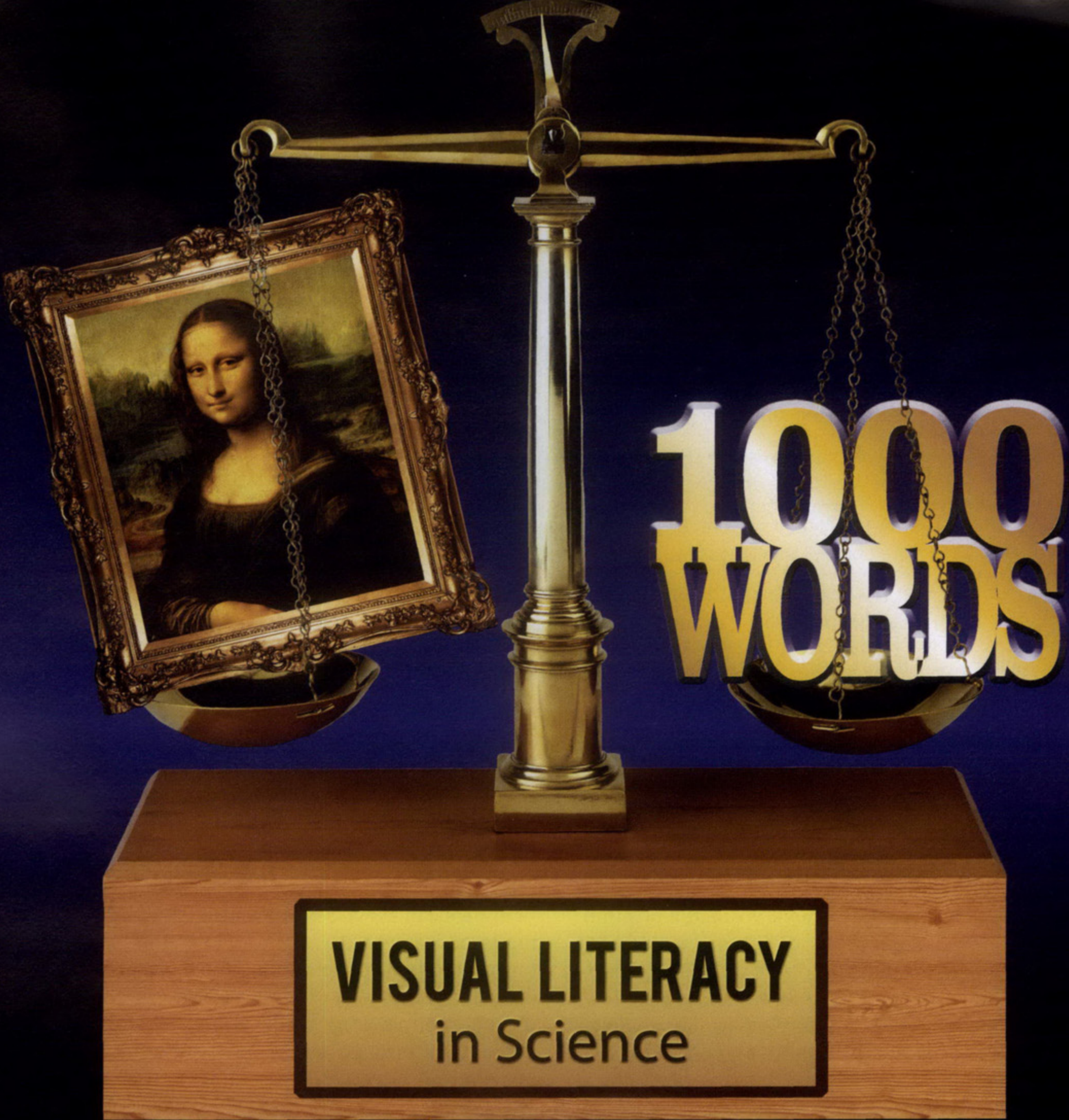


by Erin McTigue and Amanda Croix

"Why do you think science books have diagrams in them?" I asked a sixth-grade student. She thought for a moment and earnestly replied, "Well, they are pretty and also show what they [texts] are talking about." In these few words, she nicely summarized the prevalent opinion of the 30 elementary and middle grade students we interviewed about science diagrams (McTigue and Croix 2008). While diagrams make the text more visually appealing and provide an image of the text, they also do much more. Subsequently, we designed a series of lessons for students to discover the many purposes of graphics in science. A particular utility of these interdisciplinary lessons is that they can be used with any science text featuring visual images.

FIGURE 1 Useful visual literacy terminology to teach students about science graphics

Terminology	Definition	Find an example in your text, record the page number, and write a brief description.
Title	Name or short description of the entire graphic, usually located on the top of the graphic and written in a larger font.	
Label	A word that names an object or part of the object. Often, the label words are connected to the image by a line or arrow.	
Caption	Brief sentence or sentences that provide information about the object. Usually these are located underneath the graphic.	
Key	If the graphic has a symbol system (e.g., maps often use symbols), the key matches the symbols to words.	
Cutaway	If the graphic is showing the internal workings (the insides) of a structure, the illustrator will use a cutaway technique so that you can see both the inside and outside at the same time.	

We started inquiring about our students' viewing practices of science diagrams because we noted a large mismatch between our instructional materials and students' reading practices: While nearly every page of the new science textbook boasted a beautiful array of complex illustrations, our students tended to ignore them. Some students admitted that they appreciated all the graphics in their new text because they could "skip over them and make the reading go much faster." After our interview project, we concluded that if our students better understood the value of graphical representations, they might be motivated to learn from them, or, at the very least, look at them.

We feel strongly that developing students' visual literacy skills in science will benefit students now and in the future for the following reasons: (1) Visual literacy is part of being an effective communicator of science (AAAS 1993). (2) In high-stakes, state-level, middle school science tests, over half of the questions included graphics, and 80% of those graphics contained essential information for answering the questions (Yeh and McTigue 2009). (3) High school science textbooks have approximately 1.3 graphics per page and science journals have about 1.5 graphics (Bowen and Roth 2002).

Turning to research for guidance (e.g., Levin 1981), we found other major reasons to pay heed to graphics: (1) Graphics can contain important and unique information that is not in the text. (2) Graphics more easily represent certain types of information than text, such as relative location. (3) Graphics can serve as organizational tools for learning (e.g., a flowchart). Rather than simply informing our students of these findings, we created a series of lessons that would lead middle-grade students to such conclusions while aiming to create interest and understanding for visual literacy. Lesson 1 provides an introduction to important terminology and Lessons 2, 3, and 4 are each aligned with the aforementioned reasons to pay attention to science graphics. Please note that these lessons are not limited to our examples, but are readily applicable to most science content.

Lesson 1: Graphical terminology

We immediately realized that we needed a common language to talk about graphics. Our students did not have the vocabulary to describe the parts of graphics, and when referring to items such as labels and captions, they tended to use generic words such as "those little blips." Therefore, we recommend a brief introduction to terminology.

First, introduce student-friendly definitions and then, as a class, apply the terms to a common diagram that is displayed onscreen using presentation software. Next, give students sticky notes to mark examples of each of the terms being introduced within their current science readings. Figure 1 provides a list of sample vocabulary and a template for students to record their findings.

Lesson 2: Redundant or not?

To challenge students to consider if texts and graphics convey the same information, present students with a graphic and the corresponding text (see Figure 2). With colored highlighters, have pairs of students highlight the text and color-code information. If a piece of information is just in the text, use the first color (e.g., yellow), if it is in both the text and graphic, use the second color (e.g., blue). Next, challenge students to consider what information is only available in the graphic. Finally, have the class discuss their findings and compare results.

In Figure 2, there is an example of both text and a graphic (adapted from an eighth-grade text) explaining plant cells in hypertonic, isotonic, and hypotonic solutions. For example, by analyzing the types of information in both sources, as shown in a sample student response (see Figure 3), it is clear that specific vocabulary (e.g., plasmolyzed) is only used in the graphic and not the text. Because students are unfamiliar with this type of analysis task, it is critical to explicitly walk through the steps before assigning it to student pairs. First, the teacher can guide students in identifying individual facts from each source and constructing two lists. Students then compare the lists and circle the commonalities. For example, the teacher can stress that certain concepts (e.g., that water is stored in a vacuole) are clear in the graphic, but absent in the text. In contrast, the text also contains much more unique information. Only the text defines hypertonic, isotonic, and hypotonic, so it would be very difficult for students to fully understand the graphic without the referent paragraph.

FIGURE 2 A graphic and corresponding text paraphrased from an eighth-grade life science chapter

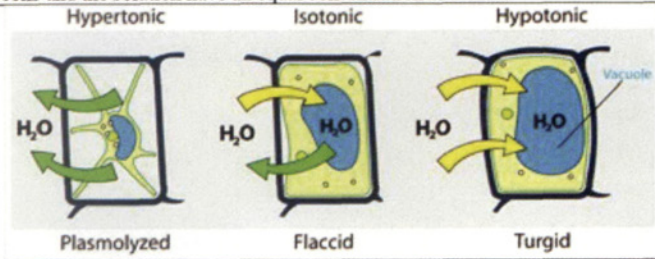
Text	Plants stay stiff due to pressure in their cells that is created by water. Plants wilt when the pressures in the cells decrease due to having less water in the cell. Water enters the cells by the process of osmosis—it is passive transport of water that depends on the concentration of the surrounding solution. When cells are in a hypertonic solution, there are more salts and other particles in the surrounding solution, so water leaves the cells via osmosis. The plant would then wilt. In contrast, when cells are in a hypotonic solution, the cell has more salts and other particles in it and the water would enter the cell through osmosis and create pressure. This pressure is called turgor pressure. The plant would be stable and not wilting. Finally, in an isotonic solution, the cells and the solution have an equal concentration of solutes.
Graphic	

IMAGE BY LADYOFHATS

FIGURE 3 Example of acceptable student responses from Lesson 2 (hypertonic/isotonic/hypotonic)

Text only	• These cells are from a plant • Plants wilt from lack of pressure • Osmosis is the process where the water moves passively • Hypertonic, isotonic, and hypotonic are defined
Graphic only	• Water enters and leaves cells in an isotonic solution • Water stays in a vacuole, and is not everywhere in the cell • Plasmolyzed cells have little water in their vacuole and the inside shrinks • Flaccid cells are ones where water is coming and going
Both	• Water leaves plants in a hypertonic solution • Water leaves cells that are in a hypotonic solution • Turgor pressure/turgid • Hypertonic, isotonic, and hypotonic are used in both

FIGURE 4 Three visual images of a volcano.

(a) Volcano photograph

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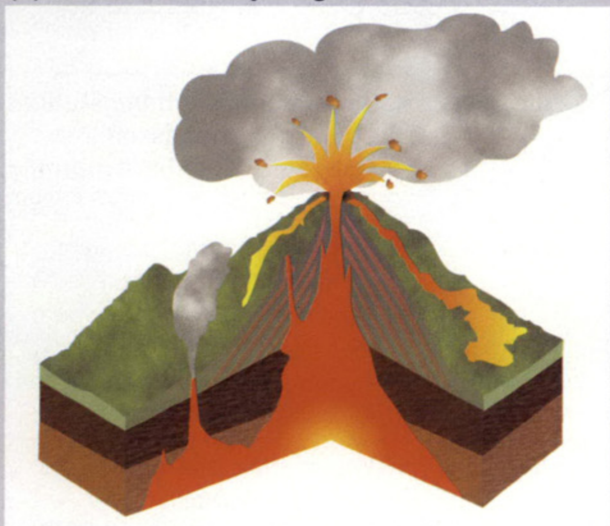
(b) Volcano cutaway diagram



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(c) Satellite imag

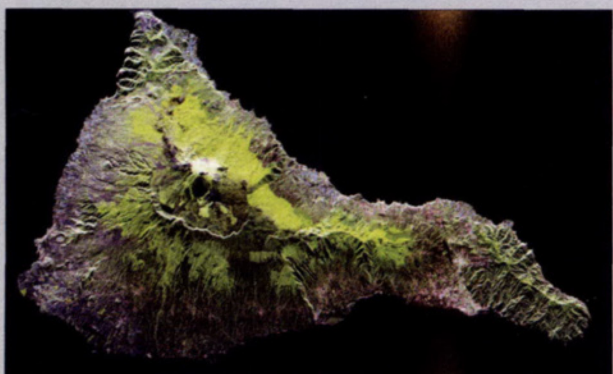
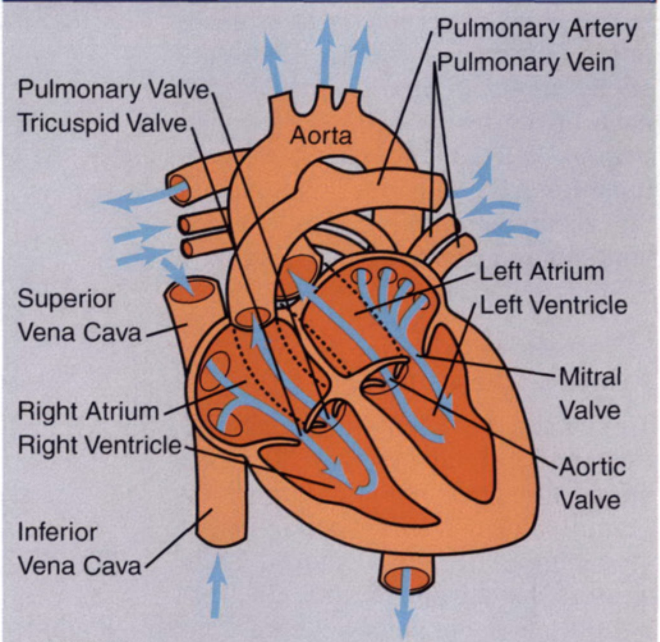


IMAGE COURTESY OF NASA

FIGURE 5 Pictorial diagram showing blood flow through the heart



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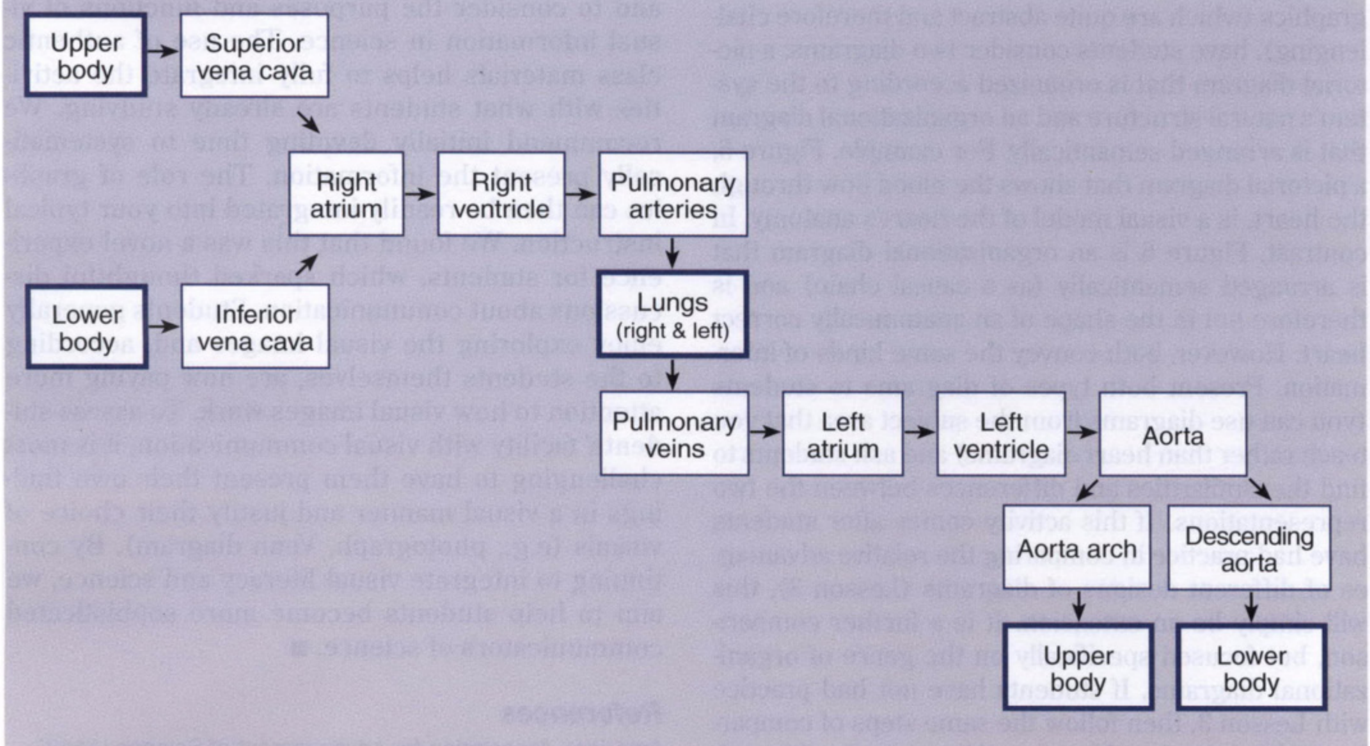
After focused instruction with one diagram, have students work in pairs to repeat the process. We recommend pairing students heterogeneously to help learners who may have difficulty decoding the text. In our experience, while few student pairs locate all pieces of possible information, students are easily able to indentify some differences between the two sources—which is the goal. Students share responses and all possible areas are noted. We recommend repeating the exercise with different diagrams to help students generalize across diagrams. Because this exercise takes considerable discussion between partners, it allows teachers time to circulate and query individual students about their understanding. The initial whole-class lesson takes approximately 20 minutes. The student-led inquiries into the text-diagram connections also require about 20 minutes of time, including the time for different groups to share their findings with the class.

If students are having difficulties finding differences, the teacher can explicitly question them to focus their attention on one aspect of the diagram. For example, in the plant diagram, many students overlook that the arrows' colors convey information.

FIGURE 6 An organizational diagram that is arranged semantically (as a causal chain)



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Asking students the reason for these colors focuses their attention on the arrows and therefore the movement of water that they represent. If students are still unsure, ask why the cell in isotonic water has movement in and out of the cell (depicted by yellow and green arrows). The teacher can then prompt students to consider if the paragraph provides such information as well.

Lesson 3: Showing the same thing?

To further explore how different categories of visual representations are equipped for certain types of communication, have students compare multiple representations on the same topic. For example, for a sample chart (see Figure 4), we selected three visual images of a volcano: a photograph of Augustine volcano in Alaska, a cross-section diagram of a volcano, and a satellite image of Teide volcano in the Canary Islands. On a large chart with the whole class, have students find and record how each visual representation conveys different types of information. We found that the teacher must initially model this by giving a few examples, but then students are eager to find differences. While it only takes about five minutes to list differences, the follow-up discussion of differences can take 20 minutes or more. More than just identifying differences, teachers want to challenge students to consider the possible advantages for including multiple sources of information. Posing direct questions to students such as "If you were the author of our textbook, what type of volcano representation would you include?" requires students to analyze how science is communicated. For example, students noted that the photograph has the advantage of being concrete and realistic, whereas the diagram would be better for learning the "parts" of a volcano. However, when placed in the role of author, students typically respond that they would not want to choose just one image. Their inability to select one single "best" image of a volcano led to inquiries into why they could not agree on which image to use.

Lesson 4: The shape of organization

To help students better understand organizational graphics (which are quite abstract and therefore challenging), have students consider two diagrams: a pictorial diagram that is organized according to the system's natural structure and an organizational diagram that is arranged semantically. For example, Figure 5, a pictorial diagram that shows the blood flow through the heart, is a visual model of the heart's anatomy. In contrast, Figure 6 is an organizational diagram that is arranged semantically (as a causal chain) and is therefore not in the shape of an anatomically correct heart. However, both convey the same kinds of information. Present both types of diagrams to students (you can use diagrams from the subject area that you teach rather than heart diagrams) and ask students to find the similarities and differences between the two representations. If this activity comes after students have had practice in comparing the relative advantages of different designs of diagrams (Lesson 3), this will simply be an extension. It is a further comparison, but focused specifically on the genre of organizational diagrams. If students have not had practice with Lesson 3, then follow the same steps of comparing and contrasting. Next, provide students with multiple examples of organizational diagrams. The type of organizational diagram will depend on a teacher's exact subject area and materials. Possible choices are Venn diagrams, flowcharts, tables, and tree diagrams (e.g., a taxonomy chart). This can be done systematically or can be discussed each time you use a new type of organizational diagram. To present organizational diagrams systematically, challenge students to consider what these sources all have in common (semantic structure). To lead them to that conclusion, discuss the purposes of each diagram and its arrangement. For example, while Venn diagrams are good for comparing and contrasting, tree diagrams are useful for showing hierarchies. After discussing the specific purpose of organizational diagrams, distribute sticky notes and have students examine science texts and mark examples of organizational diagrams. The findings of their diagram search can be recorded and visually displayed on a class chart.

Closing thoughts

The goal of these lessons is to guide students to find the value in graphical representations rather than dismissing them as simply decorative or unnecessary. These activities will challenge students to move beyond a passive approach to graphics and to consider the purposes and functions of visual information in science. The use of authentic class materials helps to fully integrate the activities with what students are already studying. We recommend initially devoting time to systematically present the information. The role of graphics can then be readily integrated into your typical instruction. We found that this was a novel experience for students, which sparked thoughtful discussions about communication. Students generally enjoy exploring the visual images and, according to the students themselves, are now paying more attention to how visual images work. To assess students' facility with visual communication, it is most challenging to have them present their own findings in a visual manner and justify their choice of visuals (e.g., photograph, Venn diagram). By continuing to integrate visual literacy and science, we aim to help students become more sophisticated communicators of science. ■

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