PICTURE PERFECT

USING QUALITY GRAPHICS TO SUPPORT ENGLISH LANGUAGE LEARNERS IN SCIENCE CLASSES

Katherine Wright, Zohreh Eslami, Erin McTigue, and Dudley Reynolds

Studies evaluating the graphics in science textbooks have recommended that teachers use eye-catching visuals to reinforce student learning objectives (Wright et al. 2014). Similarly, the *Next Generation Science Standards* (NGSS Lead States 2013) suggest that science teachers use visuals to teach English Language Learners (ELLs). However, little research has focused on the role visuals play in helping young ELLs acquire second-language skills and content-area knowledge.

Using visuals is a common and recommended practice for teaching ELLs, but there's reason to question the effectiveness of current methods. In 2009, only 3% of eighth-grade ELLs scored "proficient" on the National Assessment of Educational Progress science exam (NAEP 2009), a level of underachievement that represents a crisis in the capability of young ELLs to advance in their scientific fields.

Unfortunately, although many sources urge teachers to incorporate pictures, graphs, and charts in ELL instructional materials, educators receive scant guidance for selecting useful and appropriate visuals. And, simply put, not all visuals are equally useful.

Based on those findings and our own textbook content analysis, in this article we recommend strategies for identifying effective visuals that support the needs of students who read and study science in a second language. In addition, because we recognize that teachers often have limited choices in print resources, we offer suggestions for using less-than-ideal visuals to build graphical literacy.

Graphics and second-language development

Using models is essential for future scientists, mathematicians, and engineers, according to *A Framework for K–12 Science Education* (NRC 2012), the *NGSS*, and *Common Core State Standards* (NGAC and CCSSO 2010). Researchers also have demonstrated the importance of graphical literacy for success in high-stakes science tests (Yeh and McTigue 2009). Accordingly, the *NGSS* advise that teachers support ELLs by incorporating graphics into classroom practice and helping these students learn to "visually represent" scientific phenomena (NGSS Lead States 2013; Appendix D, p. 9).

One way to address this need is to strategically use science graphics during instruction. However, a recent survey about second-language teachers' instructional practices didn't even ask about visual aids (Zohrabi, Sabouri, and Behroozian 2012). Still, the topic repeatedly came up in the teachers' open-ended responses, revealing their interest in using visual aids. When asked about the constraints they

A well-designed scientific graphic is more than an interesting image. It should also meet various criteria, such as modeling a system, supporting related text, and contributing to content knowledge.

face teaching with current texts, 35% cited the lack of visual aids, and 60% identified uninteresting and unattractive graphics (Zohrabi, Sabouri, and Behroozian 2012).

One reason visual aids are popular among ELL teachers is that they support second-language (L2) vocabulary development. Over the years, researchers and teachers have agreed that vocabulary is crucial to an ELLs' overall academic performance (Jean and Geva 2009; Mehrpour and Rahimi 2010; Saville-Troike 1984). Furthermore, as students advance through grades, the difficulty and importance of content vocabulary increases, explaining why students need additional support to understand their texts. Graphics provide this support, serving as a visual dictionary that allows students to infer word meaning without disengaging from the reading activity. Science textbooks, with purposefully selected, well-identified, and integrated visuals, enhance L2 vocabulary development and support content knowledge.

Concerns posed by graphics

Both native and non-native speakers face challenges when interpreting visuals, but poorly selected graphics are more likely to confuse ELLs. That's because textual context helps readers interpret a graphic and vice-versa. For example, Roberts et al. (2013) found that even older, native-speaking students struggled to isolate important information in a graphic. They also required direct instruction to understand that a graphic might present different information from the text, a difficulty that's magnified for ELLs working harder to understand the language.

Effective visuals are those that reduce rather than add to task complexity. Previous work has demonstrated that complex diagrams, though useful for adults, might not easily transfer to young learners (McTigue 2009). Graphics selected for ELLs should support scientific vocabulary development without making interpretation more difficult.

Identifying strong graphics

Using existing research and a graphics analysis system for science texts (Slough et al. 2010) we've developed five simple questions teachers can use to determine the value of graphics in science materials. We also provide representative examples from a contemporary science textbook designed for second-language learners (Wright et al. 2014). Our goals are to help teachers assess visuals before presenting them to ELLs and determine when students need additional help understanding them, as well as to create supplementary reading and visual materials for their second-language students.

Question 1: Does the graphic model a system?

Textbooks explain many complex science topics in words, but we often better understand these topics as diagrams. Scientific systems usually have many interconnected parts that make them difficult to describe in linear sentences. For example, consider Figure 1a, a visual from a lesson on the seasons. While the original text describes the Earth's path around the Sun, the diagram offers a framework for visualizing the action. Although imperfect (e.g., the Earth is disproportionally large compared with the Sun), the diagram succeeds in modeling an entire system and is preferable to the simpler image in Figure 1b that shows only a discrete part of the process taken out of context. Unfortunately, previous evaluations of U.S. science textbooks demonstrated that most published visuals tend to depict isolated units of a complex idea (Slough et al. 2010).

FIGURE 1A

This "system" diagram illustrates the Earth revolving around the Sun. (The model shows Earth larger and closer than it actually is in relation to the Sun.)

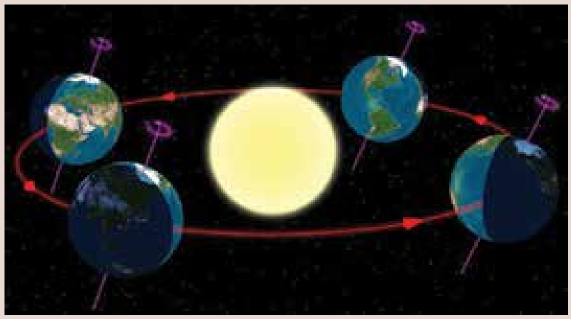

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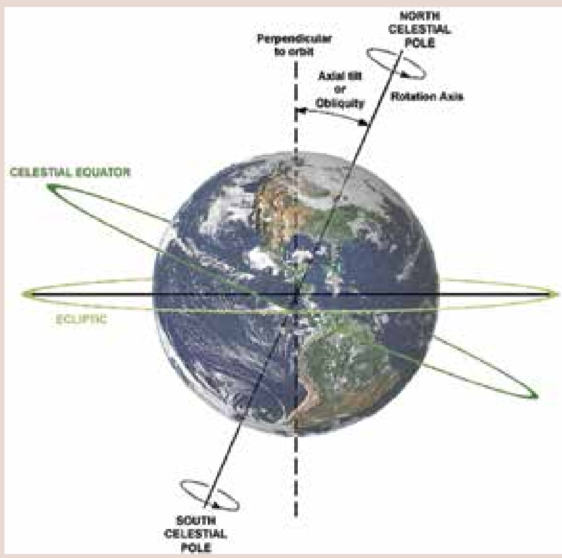
FIGURE 1B

This "unit" illustration models Earth's axis but shows only discrete aspects of the planet's rotation in the larger context of the solar system.



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Question 2: Is the graphic near relevant text?

Locating graphics near corresponding text prompts students to examine and make important connections between visuals and text. Conversely, when visuals don't appear close to corresponding text, such as on a different page, students become less likely to persist in finding, examining, and interpreting the graphic.

Question 3: Does the text reference the graphic?

Both native and non-native speakers need encouragement to examine and analyze textbook graphics (Hannus and Hyönä 1999) and connect the information to the text. References such as "See Figure 1" help but may not be enough to engage the reader with the visual information. When an author directly contextualizes the text visual with visual information (e.g., "pause now and look at the photograph to see…"), students likely will examine the graphic more thoroughly.

Question 4: Does the graphic have descriptive captions?

Captions help readers identify the visual, connect it to the text, and clarify ambiguous interpretations. If captions lack sufficient description and context, students could misinterpret the visual's purpose and incorrectly fill in the gaps themselves. For instance, Figure 2 presents a potentially problematic visual from a science textbook. Without a descriptive caption, an ELL reader might misinterpret the arrows to imply movement rather than the intended genetic relationship. Such confusion reduces overall reading comprehension.

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Question 5: Does the graphic or its caption contribute to content knowledge or confuse the reader?

As noted earlier, effective graphics should reduce the already complex task of reading science texts. Figure 3 provides a sample text and representative visual from a lesson on cells. We created three caption options, the first aligning with the minimum requirements discussed in the previous question. The second option, which actually appeared in the text, has both relevant and superfluous information that would likely add to an ELLs' cognitive load. The third option, identifies the image, allows students to make a clear connection between the text and graphic, and mirrors vocabulary in the main text.

Tips for teachers

With tight budgets and limited resources, teachers can't always choose the teaching materials that best meet their students' diverse needs, but they can take simple steps to compensate for problematic graphics.

Disjointed graphics and text

Many problems associated with poor graphics correspond to their relationship with relevant text. A savvy teacher can address potential problems when graphics don't (a) appear near relevant text, (b) include references to the text, or (c) connect to text through captions. The visual and its caption in Figure 4 (p. 46) demonstrate the difference between genetic and environmental variations. Nowhere, though, does the text specifically mention trees or forests, so an ELL would likely misunderstand the purpose of the graphic.

A teacher can use a variety of strategies to avoid student confusion. If time permits, teachers could create their own captions to clarify the visual, perhaps one that reads, "We see variation in forests. Even though these trees are in a similar environment, they will grow taller or wider because all trees need sunlight and some trees get more than others." Teachers also could handwrite this message in the text prior to making copies, write it on a white board, or write it on a sticky note placed on a textbook page. After modeling these "repaired captions," and as students become more informed graphics users, teachers should challenge them to rewrite poorly written captions.

Superfluous captions

Unclear or superfluous captions also pose problems in textbook graphics, but these can be turned into teaching opportunities. We know that ELLs' reading comprehension improves when they annotate text and identify the main idea of a paragraph (Lo, Yeh, and Sung 2013). Teachers can apply the same concept to graphics.

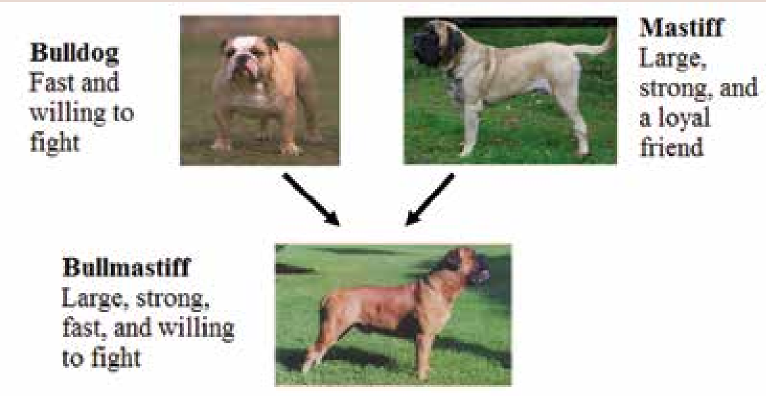
After the class has read the main text, ask students to describe how it relates to the visual. Next, ask them to summarize the caption, which will help identify the main idea. Students should then be able to highlight information that directly supports the idea, separating it from extraneous details.

Teaching to identify a visual's purpose

One of the most striking differences between young readers and subject experts is that the young tend to view a textbook as an authoritative source of information rather than

FIGURE 2

The lack of a descriptive caption confuses the meaning of the arrows in this graphic representation of the genetic relationships among breeds of dogs.



BULLDOG IMAGE DETROITBASKETBALL/WIKIMEDIA COMMONS, MASTIFF IMAGE RADOVAN ROHOVSKY/WIKIMEDIA COMMONS, BULLMASTIFF IMAGE CHRISDELIMANETTO/WIKIMEDIA COMMONS-SA.3.0

FIGURE 3

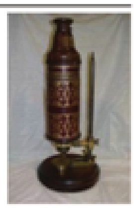
Sample text, corresponding graphic, and possible captions.

Text and visual from a seventh-grade science lesson on cells

"Robert Hooke was the first person to describe ***cells***.

In 1665, he built a ***microscope*** to look at tiny objects.

One day, he looked at a thin slice of cork. Cork is found in the bark of cork trees. The cork looked like it was made of little boxes." (Supreme Education Council, 2010)



Simplistic Caption	Caption with Superfluous information	Ideal Caption
An early microscope	Figure 3: In the 11th century, the Arab Alhazan was the 1st to describe the use and the characteristics of glass lenses. Around 1600, the microscope was invented, possibly by Hans and Zacharias Jansen	Figure 3: A microscope similar to the one Robert Hooke may have used when he first described cork cells.

Microscope © Alan.hawk / Wikimedia Commons/ CC-BY-SA.3.0

as a contribution to a larger field (Haas and Flower 1988). Therefore, ELL readers will likely view published visuals as "correct" and assume any confusion is a result of their own lack of knowledge or language skills. Teaching students to question an author's purpose in including a visual supports reading comprehension and provides a strategy for critically interpreting graphics. One approach, called rhetorical reading, offers strategies to encourage students to think beyond the text and consider the author's thought process in creating it (Warren 2012).

To illustrate, look again at Figure 2 (the bulldog, mastiff, and bullmastiff). This image from a lesson describing how genetic material is passed through generations offered no additional captions. Rather than just telling a class how the visual supports the content, a teacher might ask why students think it was included. A class discussion of the author's purpose might lead to understanding the visual as an example of genetic heredity. Afterward, students would be more likely to remember the information because they were more deeply engaged with the material.

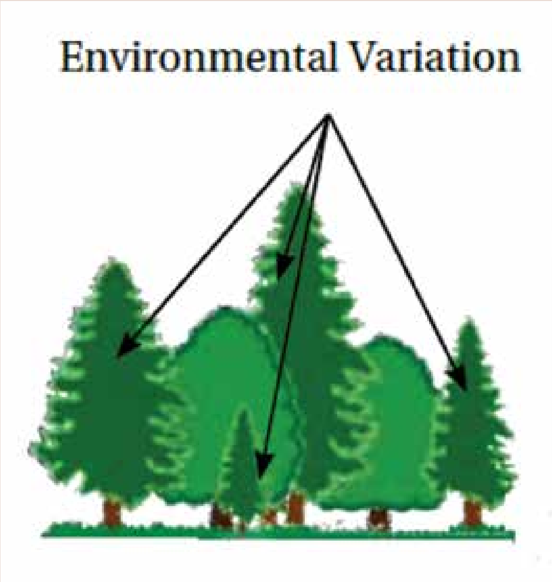
Conclusion

Although visuals have long been valued as an asset to ELL instruction (Cunningsworth 1984; Texas Education Association 2011), teachers need to consider how well these visuals support both second-language and content knowledge development. Graphics should provide a visual dictionary, allowing students to define unknown vocabulary without breaking from their reading activity. Correctly designed graphics can reduce the cognitive load on students reading in a second language and enhance content knowledge. While many ELL instructors don't have the freedom to self-select teaching materials, they can make small adjustments to their instructional approach to ensure graphics don't confuse learners.

Graphics hold great potential to support L2 acquisition and content area knowledge development. However, when not purposefully selected, they can

FIGURE 4

What is this visual of trees trying to tell us? Without a caption, or a savvy teacher, students wouldn't know.



impede learning by confusing young ELLs. As with so many aspects of science education, a knowledgeable, well-prepared teacher can make all the difference. ■

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