# Beyond "See Figure 1"

## A Heuristic for Writing About Figures and Tables

***By Cary Moskovitz***

*Visual elements such as graphs, tables, and diagrams are essential components of scientific writing. Although scientific writing textbooks and guides often contain information on how to design such visuals, little has been written on how to effectively discuss those visuals within the text. This article offers a novel heuristic for teaching students how to effectively execute these "passages about visuals" in a way that is both conceptually simple enough to be understood by novices yet rich enough to accommodate the complexity of expert scientific writing. The heuristic consists of a set of "moves": announce, orient, observe, and explain. Following an explanation of the moves, readers are walked through a variety of examples showing the moves in context and noting the different ways the moves are arranged and executed in published scientific research articles. Pedagogical implications and approaches for using the heuristic in the classroom are then discussed.*

Scientists and teachers of scientific writing are well aware of the importance of visual elements (e.g., graphs, tables, diagrams, and maps) in communicating science. What is less appreciated is the essential role of the written elements that nearly always accompany these visuals. Some of these elements—titles, captions, legends, and data labels—may be considered part of the visual itself. The focus of this article is the written material that is *not* in the visual or legend. I call these "passages about visuals," or PAVs.

Widespread dogma says that figures should speak for themselves, but only novices believe that "see Figure 1" is sufficient as a reference. Even though PAVs are a standard part of scientific writing, they are overlooked or oversimplified in textbooks and guides to scientific writing. Science students can find plenty of detailed instruction on how to create figures and tables (and even how to craft captions), but they will find little on how to discuss figures in the papers or articles where those visuals appear.

### The need for a new approach

In their classic book, *Writing in the Sciences: Exploring Conventions of Scientific Discourse,* Penrose and Katz (2004, p. 87) took a step in the right direction to provide guidance on this topic:

> *The relationship between data and generalizations is easily demonstrated by looking at how tables and figures are referred to in well-written reports. Tables, graphs, and other visual representations are essential tools for reporting scientific results, but it is important to keep in mind that graphics only present the data; the generalizations needed to interpret those data must be provided in the text.*

Penrose and Katz (2004, p. 87) then give readers this two-step model for writing about visuals:

> *"Refer readers to the visual explicitly."*
>
> *"Tell them what patterns to notice."*

While clearly acknowledging the importance of PAVs, Penrose and Katz (2004) do not account for the different types of visuals used in scientific writing and the different kinds of rhetorical tasks that PAVs must therefore perform. In fact, existing scientific writing textbooks tend to limit discussion of visuals to those that present data or findings—and even then, the textbooks only address the role of these visuals in supporting generalization and interpretation. However, figures and tables regularly serve other purposes as well. In the introduction, a map may show readers the geographical location under study, or a flowchart may present a theoretical model. In the methods section, a diagram or photograph may illustrate the experimental setup. In the results section, a table may present demographic data for the sample.

Given the lack of a sufficiently articulated model for teaching the writing of PAVs, I have developed a heuristic that accommodates the broad range of rhetorical functions that visuals accomplish in scientific discourse. The "moves" I present in this article are inspired by the work of linguist John Swales. In their rhetorical analysis of the introductory sections of contemporary scientific research articles, Swales and Najjar (1987) identified these standard moves:

1. Introduce the topic; establish that the research area is of significance.
2. Selectively summarize relevant prior research.
3. Show that prior research is incomplete by articulating a gap in that research.
4. Explain how the current research helps fill the gap.

Although Swales developed these moves as a descriptive device, they have been widely used as a heuristic for helping scientists learn how to craft introductions to their research reports. (In fact, Penrose and Katz [2004] use Swales's moves for teaching introductions.) Teaching PAVs through a similar set of archetypical "moves" seemed like a promising approach.

## The heuristic

I developed the PAV heuristic in relation to a set of empirical questions:

- Where are visuals typically used in science research papers?
- What are those visuals intended to communicate?
- What kinds of prose do scientists use to facilitate that communication?

I examined these practices in leading science journals, then refined the moves by testing them across a wide range of scientific disciplines, ensuring that the schema was broadly applicable. The final version of the heuristic is presented in Figure 1.

Figure 2 shows these four moves in context, with an example from the *Journal of Economic Perspectives* (Cutler et al., 2006) that investigates human life span and mortality across countries and age groups.

Following the opening *announcement* (yellow in Figure 1), the remain-

**FIGURE 1**

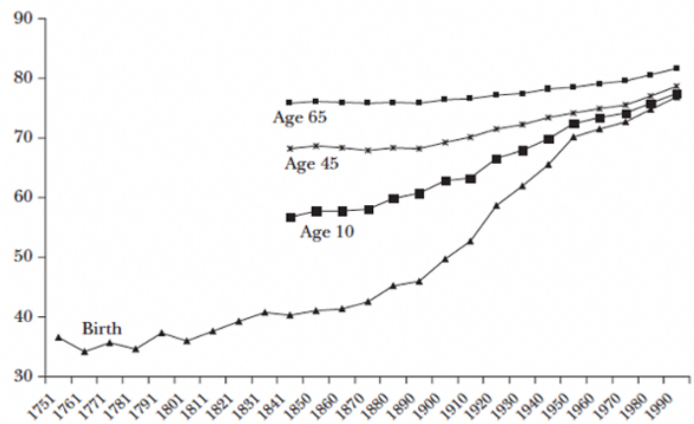
**A heuristic for PAV moves in scientific writing.**

| | |
|---|---|
| ***Announce*** | When should readers look at the visual? |
| ***Orient*** | What are readers looking at? |
| ***Observe*** | What are the important features or trends you want readers to see? |
| ***Explain*** | Why are those observations important? |

**FIGURE 2**

**Example showing the four PAV moves in the *Journal of Economic Perspectives.***

*Figure 2*
**Expected Age at Death, England and Wales**




*Source:* Data for 1751–1841 are from Wrigley and Schofield (1981, Table 7.15, p. 230); data from 1841 are from the Human Mortality Database.

Figure 2 shows trends in life expectancy by age in England since 1840. Between 1841 and 1950, life expectancy at birth increased by 30 years, while life expectancy at age ten increased by only half that amount. The decline in infectious disease explains this disparate age pattern. In 1848, 60 percent of deaths in England were from infectious disease. Between then and 1971, infectious disease mortality declined by 95 percent. Since infants and children are the most vulnerable to infections, their mortality rates were most affected by the decline in infections.

*Source.* Cutler et al. (2006), p. 5.

der of the first sentence does an *orient* move (blue), describing the figure's general content. The next sentence makes an *observation* (green), directing readers to locate the years 1841 and 1950 on the x-axis, then notice that the gains in age at death (y-axis) during that period are greater for the lowest curve (birth) than for the other three curves. The remaining sentences *explain* these trends (red), telling readers why the curves have these patterns.

Although this example shows all four moves, only the announcement move is ubiquitous in scientific writing. The others, as I discuss in this article, are used in various combinations. First, I describe each move in greater depth.

### Announce

Announcements are the "see Figure 1" gesture, the straightforward calling of attention to the visual itself. Announcements are nearly universal in PAVs: When authors include a figure or table, they need to tell readers when to look at it. Most visuals have only a single announcement, but it is common to see multiple announcements for the same visual. Authors may, for instance, want readers to first look at a diagram in the introduction to understand the nature of the research project, then again in the methods section to see specific experimental details.

### Orient

Orientation moves provide information that helps readers make sense of a visual. They usually tell readers what kind of thing the visual is and may provide other information as well. Because there are many types of visuals and audiences differ in their familiarity with each type, authors should choose orientation material based on the expected readership. Authors should also decide which orientation information should be in the PAV itself versus in the caption.

### Observe

Observations focus readers' attention on specific aspects of a visual, such as relationships, trends, or key features. Even though there are many varieties of *observe* moves, I find it pedagogically useful to categorize observations for visuals that present data in two general ways:

- *Point observations* direct readers' eyes to a specific spot on a graph or a cell in a table to see things such as maxima or minima, inflection points, and outliers. (If you can place your finger on it, it is a point observation.)
- *Trend observations* ask readers to scan their eyes across a region of the visual to notice a pattern (e.g., the negative slope of a line, the bimodal nature of distribution, the clustering of a group of curves, or the decreasing values in a table column).

### Explain

Explanations tell readers how to think about observations that have been made. Some *explain* moves suggest reasons for a feature or observed trend. Others are inferences, in which authors generalize from observations by answering the question "What do these observations mean?"

## The moves in context

We may find these moves in a wide variety of combinations and orders, but my informal survey of published examples suggests some noteworthy trends for PAVs in IMRD (Introduction, Methods, Results, and Discussion) structured papers. First, all four moves do not occur in every PAV. Second, we often see these moves in the order in which I present them in this article—announce, orient, observe, explain—but this is far from standard, as readers will see in the examples I share.

Finally, moves are more or less common depending on the section in which the PAV appears. Visuals in the introductory part of a paper are frequently schematic in nature, such as illustrating concepts, locating the study geographically on a map, and so on. PAVs for such visuals usually include orient moves and perhaps observations. In methods sections, we typically see visuals that present experimental details; these will usually include orient and observe moves, but they often include explanations as well in which authors articulate the rationale for their methodological choices. In results sections, we may see all four moves together, or the explanation may not be included until the discussion section. Because visuals are rare within discussion sections (when separated from results), any PAVs there will address visuals already mentioned; thus, PAVs in discussion sections rarely contain orientations and observations because those moves will have already been performed. I map out where each move is most likely to occur in Table 1.

I also note that announcement moves are not always placed at the beginning of the PAV. Scientists frequently place announcements at the end of an orientation statement. Other times, authors first make their observations as if the visual were not present and only announce the visual afterward. I feel that this last approach is less desirable for readers, as it encourages them to try to understand

**TABLE 1**

**Where the four PAV moves are likely to occur in IMRD research articles.**

| MOVE | Intro | Methods | Results | Discussion |
|---|---|---|---|---|
| *Announce* | always | always | always | always |
| *Orient* | usually | usually | usually | rarely |
| *Observe* | sometimes | usually | usually | rarely |
| *Explain* | sometimes | sometimes | sometimes | usually |

*Note.* IMRD = Introduction, Methods, Results, and Discussion; PAV = passages about visuals.

**FIGURE 3**

**Example from the introduction of a medical sciences research article.**

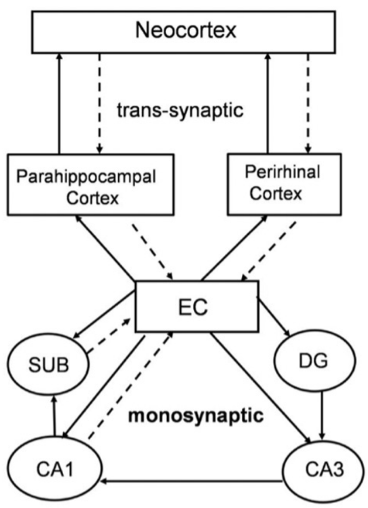



**Figure 1. Monosynaptic and trans-synaptic cortico-hippocampal and cortico-cortico connections.** Solid lines indicate projections radiating out from the EC, dotted lines indicate projections to the EC. Monosynaptically connected regions are connected across one synapse. Trans-synaptic regions are separated by more than one synapse. doi:10.1371/journal.pone.0031302.g001

As shown in Fig. 1, the EC is monosynaptically connected to other hippocampal subregions and it is trans-synaptically connected with affected regions in the temporal and parietal lobes [2,3]. One of the most intriguing and poorly explored questions in the field is whether…

*Source.* Liu et al. (2012), pp. 1–2.
*Note.* The PAV contains only an *announcement* and *observation*. All orientation

details as they read without the aid of the visual—until they reach the end of the passage and see the announcement, at which point they may need to reread the passage while examining the visual. I also suspect that students do better work if they tie their presentation of findings more explicitly to their visuals.

Visuals in research articles are almost always accompanied by captions. Norms regarding what is placed in the caption versus in the main text vary considerably across disciplines and publishing outlets, and limits on article length can play a role as well. Authors (and sometimes editors) may relegate most or even all of the orientation material to the caption. Deciding what should go in the main text versus the caption can be difficult for both novices and experienced researchers. In some journals, observations may also be placed (or repeated) in the caption.

The PAV heuristic can be useful in thinking through these choices. In making these decisions, students should try to design the readers' experience: What is useful for them to know *before* they move their eyes to the visual—to prepare them for it? That information should go in the PAV. What details are better placed close to the visual for easy and possibly repeated reference? That information should be included in the caption.

## Examples

I next present a number of examples showing different types of visuals and PAV structures across different scientific disciplines. Due to space constraints, and to make it easier for readers to grasp the concepts of my schema, my examples are on the short side of the spectrum. Science, technology, engineering, and mathematics (STEM) researchers in some

**FIGURE 4**

**Examples of PAVs in methods section of an experimental paper.**

A

A high-speed stereo camera system was used to determine the 3-D flight path trajectories. Fig. 2 shows the spatial arrangement of the equipment in top-view. The stereo system consisted of two monochrome high-speed cameras … equipped with 35 mm lenses (*AF-S DX NIKKOR*). The cameras were positioned in the terrain with robust tripods (Gitzo GT5561SGT). The distance between the camera sensors and a reference point on the wall were determined by a laser-based distance sensor (*BOSCH GLM 250 VF Professional*). For distances up to 250 meters the measuring error was ±1.0 mm. The angular displacement between both cameras was 32.45°; camera #1 was positioned perpendicular to the dam wall (in the horizontal plane). A cable connection between both cameras via BNC (bayonet neill concelman) and TTL (transistor–transistor logic) signal synchronization ensured a simultaneous frame capture. Furthermore, each camera was connected to a separate computer via LAN (local area network) controlling the camera settings.

B

The experiment was conducted in three adjacent testing rooms Figure 1a)… A one-way key system was installed in each of the doors from the middle room into each of the side rooms. The keys consisted of wooden pegs that could be inserted on the subject's side of the door into a round metal hole in the track of the door. This blocked the path of the door unless the key was removed by the matter (see Figure S1a). Removing both keys simultaneously was impossible due to the distance between them. We thus created a setup in which bonobos in the middle room could determine whether to unlock a door(s) and which door to unlock first.

*Sources.* Ponitz et al. (2014), pp. 3–4; Tan & Hare (2013), p. 2.
*Note.* Panel A: Orientation followed by observations, without rationale. Panel B: Includes rationale for some of the methods.

fields frequently employ much longer passages when discussing visuals; teachers who use my approach should be careful not to mislead students into thinking that longer PAVs are necessarily undesirable. I begin with an example from an introduction, followed by examples from other parts of the typical IMRD structure.

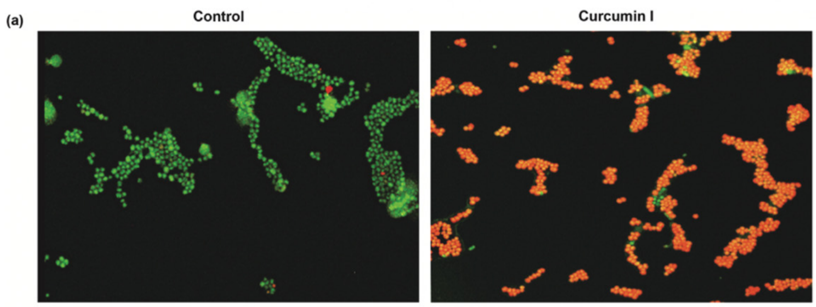
While rarely addressed in science writing textbooks, visuals (usually figures rather than tables) are often included the Introduction. These visuals typically contextualize the research project, communicate its scope, or present other information that clarifies the nature of the investigation.

Figure 3, from the Introduction of a medical sciences paper, provides an example with only two moves: the PAV goes straight from announcement to observation, with all orientation work handled in the caption.

Visuals included in methods sections are often diagrams of experimental apparatus. PAVs for these figures typically include orientation moves, followed by detailed observations describing the experimental procedure in reference to the figure, as is shown in Figure 4A. A common variation is shown in Figure 4B, in which observations (green) are accompanied by an explanation (red) that provides the rationale for the methods described.

**FIGURE 5**

**Example of figure panel presenting results from a microbiology paper.**




Curcumin I induced membrane damage of cells was visualized by epifluorescence microscopy using fluorescent probes SYTO 9 and PI which selectively stain live and dead cells, respectively. The representative microscopic images (a merged view of both channels) of control (untreated) and curcumin I (25 µM) treated have been presented in Fig. 7A. It can be clearly seen from Fig. 7A that untreated control S. aureus cells appeared predominantly green (demonstrating live cells); whereas the curcumin I treated cells appeared substantially red (indicating dead cells)…

*Source.* Tyagi et al. (2015), pp. 9–10.

Once we move into the results section, we almost always see *observe* moves. The next example (Figure 5) is from the results section of a biology paper on the antibacterial effects of curcumin. In the PAV, we see the orientation move (blue) followed by the announcement (yellow) and then the observation (green).

Research papers in some journals

**FIGURE 6**

**Example of table presenting results in an environmental science article.**

Table 1. Physical and chemical parameters of typical samples from the Odzi River (March 1993)

| Parameters[a] | Sampling site | | | | | |
|---|---|---|---|---|---|---|
| | OZ 1 | OZ 2 | OZ 3 | OZ 4 | OZ 5 | MU |
| Temperature (°C) | 16.8 | 17.2 | 17.5 | 27.4 | 28.0 | 28.0 |
| pH | 8.42 | 8.70 | 8.20 | 8.35 | 7.02 | 6.02 |
| Conductance ($\mu S\,cm^{-1}$ at 20°C) | 45 | 53 | 49 | 71 | 92 | 105 |
| TDS ($mg\,l^{-1}$) | 54 | 50 | 64 | 135 | 105 | 165 |
| TSS($mg\,l^{-1}$) | 42 | 40 | 44 | 63 | 71 | 94 |
| BOD ($mg\,l^{-1}$) | 2.4 | 3.8 | 3.9 | 3.5 | 3.2 | 2.6 |
| Total P-$PO_4^{3-}$ ($mg\,l^{-1}$) | 0.50 | 0.60 | 0.68 | 0.63 | 0.73 | 0.85 |
| N-$NO_3^-$ ($mg\,l^{-1}$) | 0.47 | 0.44 | 0.44 | 0.88 | 0.96 | 0.59 |

[a] Mean of duplicate determinations.

Five physical parameters and three chemical parameters were determined for six batches of aqueous samples from six sites over a 9-month timespan (January–September 1993). Table 1 summarises the mean values of the various parameters monitored at six selected points along the river during March1993. A perusal of the data shows the water pollution increases as the river descends from the slopes of highlands to the plains.

*Source.* Jonnalagadda & Mhere (2001), p. 2372.

have a single, combined results and discussion section rather than two separate sections. PAVs in these papers often contain all four moves. The next two examples, a table and a figure, come from the results and discussion section of an environmental sciences paper on water pollution (Jonnalagadda & Mhere, 2001). In Figure 6, we see three moves: The brief announcement of the table (yellow) is followed by orientation to the table (blue); the observe move (green) is what I've called a "trend" observation, guiding readers in seeing the general increase of values from left to right—particularly for TDS (total dissolved solids) and TSS (total suspended solids) in the middle two rows.

In Figure 7, we see all four moves. Note how the authors explain (red) the qualitative difference between the lower three curves (OZ 1, 2, and 3) and the others, using knowledge from outside of study to make sense of the observed trends. Also note that the authors use both categories of observation: trend observations in the first green sentence and point observations in the second.

## Pedagogical applications and implications

The set of moves described in this article can serve as a useful heuristic, revealing patterns in how scientists write about visuals that tend to go unnoticed. Though this schema may have value as a tool for studying scientific writing practices, I focus here on its use in teaching. There are at least three pedagogical ways to use the PAV heuristic: as a tool for observing how experts write, as a checklist for writers, and as a guide for giving feedback.

### *Reading-as-writers exercises*

The PAV heuristic can aid students in learning how experts in a particular discipline write about the kinds of visuals the students might themselves use, revealing patterns in the otherwise bewildering variety of PAVs students may encounter when reading research articles. Before attempting to implement these moves in their own writing, students will benefit from exercises that let them identify and code PAVs in model papers. Having students analyze counterexamples (papers or passages lacking expert use of PAV moves) can be useful, too, especially in papers from prior offerings of the same course. These exercises can be done even in courses in which enrollment

**FIGURE 7**

**Example of figure in results and discussion section of an environmental science article.**

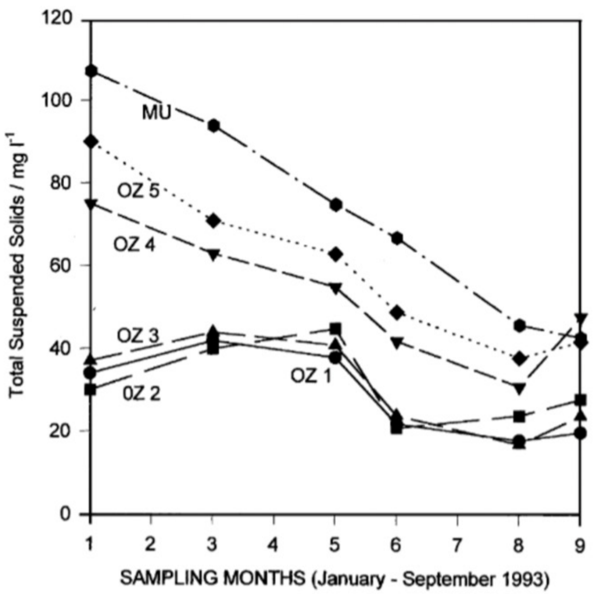



Fig. 3. Seasonal variations in the levels of total suspended solids at six sampling sites.

Figure 3 illustrates the seasonal variation in the TSS values. At the three sites in the upper reaches of the river (OZ 1-3), levels of TSS were in the same range and low. Again total suspended solids recorded highest at MU in the rainy season (107 mg $l^{-1}$) and decreased to as low as 40mg $l^{-1}$ in the dry season. Higher levels of TSS that were observed at OZ 4 compared to the upper reaches could be due to runoff waters from the farms in the upper reaches. The TSS levels at OZ 5 increased further due to incoming water from the Mutare River.

*Source.* Jonnalagadda & Mhere (2001), p. 2373.

is too large to offer students opportunities to do their own writing, such as introductory-level lecture courses. These PAV coding exercises also lend themselves to small-group work, after which students can report their coding back to the class, compare with other groups, and debate their choices. An example of a handout for this activity is given in the online appendix.

### *During the writing process*

Students can be asked to use the heuristic as a guide while drafting and revising, as they check their own PAVs for each figure and table and think about which moves they should include and whether they have executed each move in ways that will be effective for their audience. A useful way to approach this is to have students imagine they were giving a talk, the visual was on a slide, and they had a laser pointer. What would they say to make sure their audience understood what they were looking at? What would they point to, and why? Even better, have students make slides with their visuals, then record themselves presenting their slides to peers.

### *In giving feedback*

The PAV heuristic offers a vocabulary that both instructors and students can use when giving feedback, whether on drafts or completed assignments. In place of the typical but often vague terms such as "unclear," the heuristic allows instructors to offer more precise and thus useful responses. It can also be used as a checklist for peer feedback by giving students a focused task for reading and commenting on their peers' papers that the student authors can understand and act on when revising. An example peer feedback activity handout is given in the online appendix.

## The importance of context

The varied examples presented in this article show that even though the four PAV moves are conceptually simple, their implementation can be varied and complex. Unlike Swales's moves that inspired this heuristic, where the complete set of moves are found in almost every IMRD paper, the moves in any PAV will vary based on where in the paper it occurs, the type of visual it is, the audience, and disciplinary conventions. In some cases, *not* including a given move will be the best choice. Therefore, even though Swales's moves might be seen as a set of requirements for an effective research article introduction, the PAV moves should be seen as a toolbox. Learning to use these tools effectively requires students to pay attention to both internal context (where the visual occurs within the paper) and external context (the discipline and the target audience).

Accommodating one's audience is, of course, important for every aspect of writing. This heuristic can help students implement this idea, but doing so requires that students know what their target audience is! Unfortunately, like so often happens with writing assignments in school settings, scientific writing assignments in college courses often do not specify an audience. Teachers who want to implement the ideas presented in this article should take care to choose and articulate the audience for their writing assignments and also to help students understand how writing for that particular audience will affect their choices in crafting PAVs, especially if students do not have personal familiarity with that audience.

Teachers should also take the students' educational context into account. Consider the differences between the two PAVs from methods sections shown in Figure 4, where one example included explanation and the other did not. In lab courses where students are provided with detailed experimental procedures, expecting students to include explanations in methods PAVs is nonsensical; they did what they did because that is what they were told to do. In advanced courses in which students design their own experiments or at least have some say in the methodology, instructing students to include *explain* moves in methods PAVs would be useful.

Context always matters in writing. When teaching the moves presented in this article, teachers need to set expectations and provide models that align with disciplinary norms, the target audience, and the realities of their students' educational situation.

## Scientific writing and scientific thinking

Critical thinking in science involves knowing how to make and articulate meaningful observations, explanations, and inferences. These abilities—both the thinking and the expression of that thinking—are strongly tied to epistemology and disciplinary expertise. Expert scientists will have developed, for example, a set of observations they instinctively look for in the types of visuals they work with regularly. Along the way, they will also have learned how to express those moves, unconsciously absorbing the language of the moves in their reading. I am optimistic that this heuristic will help students develop skills not only in scientific writing but also in scientific reasoning.

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