Diagrams: Assessment and feedback

Schedule	prep (30 minutes): photograph and upload student photos homework (1 hr): students evaluate diagrams class discussion (20 minutes) follow up: second homework

Materials	images of student work students need access to the internet for homework projector for in-class discussion

Set-up	in class: projector, student feedback on

Background:

Introductory science courses often require students to construct precise diagrams to represent phenomena and make predictions. These include things like free-body diagrams, light-ray diagrams, maps of field lines, scale models, punnet squares, anatomical drawings, and graphical representations. Instructors expect that students will adopt a certain rigor and precision when constructing these diagrams, but we want that rigor and precision to be an aid to sense-making — helping make ideas more precise — rather than meeting seemingly arbitrary requirements set by the instructor.

By giving students the authority to develop their own representations and establish requirements for these, the sense that these are arbitrary requirements diminishes and students are more likely to see modeling and diagramming as a sense-making activity. The practice of peer assessment can help students critically evaluate and improve their representations. However, it can be difficult for instructors to manage and is not without risk: students can be reluctant to critique their peers, they may not think of themselves as having the necessary expertise, and might view this kind of feedback as the job of the instructor. In addition, there is no guarantee that students will employ greater rigor and precision as a result of peer assessment; we have all had experiences where that feedback is of little use. In this lesson plan, we describe one approach for peer assessment that can establish norms for diagrams in a way that is student-driven, where students retain agency and authority in assessing and improving their work, and the instructor can help shape that feedback so that it is productive and aligns well with disciplinary norms. In short, students will develop their own representations, describe the important features, and then use those to evaluate others' diagrams (posted online).

If it is critical that your students employ and understand canonical representations, these initial steps, where they generate their own representations and provide feedback on others, can be understood as a preparation for that future learning. Students can eventually compare the representations they developed to those that scientists use, and better understand the affordances (and shortcomings) of standard scientific representations.

Activity set-up:
This activity begins with each student generating a representation, usually as part of a homework assignment. This assignment should occur when some ideas have been established, and students will be able to justify the choices that they made. On the other had, you should not be so far along that you do not anticipate much variation in the diagrams (a few days into a new topic, but not the day before the test).

Assign a problem that requires diagramming and ask students to note the features of their diagrams that they find significant.

For example, when learning about light we asked the following:

A. Consider the dimensions of the actual human eyeball with only an iris, pupil and retina. Draw a diagram to represent how the light rays from the outside world would hit this retina.
B. Clearly explain each part of your diagram in words. Make this a complete, gapless story of what happens to the light as it travels from the Sun to your screen. Ultimately, readers should have a very clear idea of what they would see and why they would see that.

When learning about energy, the following prompt was used:

A. In class we've been discussing the energy transfers and transformations that occur when you release a basketball that's been held underwater. Draw a diagram to represent those transfers and transformations that occur *after the ball has been released, but while the ball is still underwater and rising*.
B. Clearly explain the important features of your diagram: for example, if you have an arrow, explain what that arrow is representing — is this a force that the ball feels? The direction the ball moves? Is it representing the flow of energy from one place to another?

And when discussing sound, we hoped to call students' attention to the fact that frequency of a plucked string does not (appreciably) change as the sound fades, and begin relating that to the observation that pitch does not change (but volume does).

A. View the slow-motion video of a rubber band vibrating. As carefully as possible, develop a representation of this vibration. (Feel free to show a few seconds and not the entire video in your graph if that's useful.)
B. Clearly explain your representation — help the reader "read" what you have drawn and how to connect that with the observations.

While we focus here on diagrams, you could consider asking students to create other kinds of representations. For example, a mathematical model for a falling parachute, or a definition for a term that you have been using but not yet precisely defined.

Once you have collected the homework, take pictures of their diagrams and post these on one of any free online image hosting sites or your learning management system. (If you're concerned about anonymity, title each student's assignment with a number.) Alternatively, you could ask students to submit the homework to you as a picture, if your students all have an easy means of taking a digital image.

Using students' explanations of their diagrams from their submitted work, develop a list of features that students consider important. From this list, create an online survey that asks students to evaluate one another's diagrams and comment on their evaluation.

Using the examples above, we might ask students to view all the diagrams and then, using the survey, select:

- Which of the diagrams clearly shows how at least one starburst of rays from an object travels and where it lands on the retina?
- Which of the diagrams clearly shows how multiple starbursts of rays from an object travel and where they land on the retina?
- Which of the diagrams have a relatively accurate sizing of objects and distances?
- Which of the diagrams shows the role of the iris in blocking light?

When considering energy diagrams, we have asked students which they think are particularly good at showing that forces are responsible for energy transfers, say, or that energy from the water is ultimately responsible for the ball speeding up, or that the ball is gaining less potential energy than the water loses.

With the rubber band, there was a great variety in choosing where the "zero" of the y-axis of the graph should be, and we asked students to comment on how they set up their graph and why, with many commenting that they did not want position to be a negative number. Others noted that the rubber band got "slower" over time, but were not precise in what that meant (a slower frequency, or slower absolute speed?) — and the survey was designed to help draw out that ambiguity.

Generally we have about 10 different features to look for and comment on, all drawn from student comments.

Prior to class, look at the student comments online and the diagrams that they found particularly good at showing one aspect or another. Be prepared to share these. In addition, look for places where there is disagreement and use class time to reach agreement — this indicates that there is a disconnect for students between diagrams and the ideas they represent, or ambiguity around what is meant by an idea. You might also select two or more diagrams that look superficially (or substantially) different but are each ones that, as an instructor, you find particularly strong.

Debrief:

The goals of the assignment and the follow-up survey are for students to consider the kinds of information that they want to convey in a diagram, or the kinds of inferences they hope to be able to draw from a diagram, and the various choices that they and other students have made to do that work.

We usually begin the debrief by saying something like (in the case of a light-ray diagram):

> So with the assignment that I gave you, I want to start off by noting that if you asked 10 scientists to answer this question, you would get 10 different representations. Which is not to say that every diagram is equally great - but that it really depends on what you're trying to represent and the story you're trying to tell. So I don't expect everyone's diagram to look the same - instead, I want you to think of all the representational choices you can make, and how to choose (or create) ones that tell the story, or help draw the inferences, that you want to tell or draw.
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> So to help us think through those choices, last night I had you look over everyone's diagrams, and not just looking at it superficially, but really scientifically: what kinds of things did you all think were important to show in this diagram? How did others in the class show (or not show) those things? Were there really clever or useful ways to show this?
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> And I want to start off by looking at two diagrams where there was a lot of disagreement. [show these on the projector] Some folks thought that the one on the left was showing "overlap" really well, while others thought that the one on the right was. And I want to hear from you about what you're noticing that leads you to say that one or the other was really doing a good job of this…

Through the discussion, solicit students' critiques of diagrams. Feel free to weigh in with your own assessments, as well. Students often rate "pretty" diagrams - those with clean lines and well-drawn images - as higher quality, regardless of their content, and we often need to push against that. Other diagrams that strike us as very different from each other will be perceived as similar, and we might ask students to compare those and discuss whether or not the diagrams tell a similar "story" or make similar inferences.

After the debrief, we then ask students to re-do their diagrams as homework, using the feedback they received on the survey along with new ideas they have after viewing others' work. We include the following, so that students know they are free to use other's ideas: "Feel free to steal techniques from others—every scientist uses representations, mathematical techniques, and experimental protocols that others invented. It's been said, "Good artists copy, great artists steal."

Resources:

This material draws from our work published in Atkins Elliott, Leslie, Jaxon, Kim & Salter, Irene. *Composing Science: A Faciliator's Guide to Writing in the Science Classroom*. Teachers College Press & the National Writing Project, 2016.