How to use direct (or "just-in-time") instruction in your science classroom

Some teachers believe that lecturing is to be avoided in the classroom. Other teachers depend too much on the "stand-and-deliver" method of instruction. Neither of these extremes is appropriate. There are *times for telling* by the teacher—in specific situations and about ideas that are carefully chosen. We'll describe when to use this kind of strategy and how to use it effectively.

The process of telling by the teacher is often referred to as direct instruction. In research on learning however, scholars call productive versions of this *just-in-time instruction*, because the choices of which ideas to expand on are often driven by students. They feel a need to know more in order to make progress, rather than having the teacher delivering information to them that they don't know what to do with.

How do you use just-in-time instruction strategically? It usually precedes an activity that students will do, in which you want them to reason with new ideas. The ideas that you will share are usually at the conceptual level and they cannot be "discovered" by students through any form of work with data or observation. Examples here are *equilibrium* in chemistry, *unbalanced forces* in physics, how the sun gives off different forms of radiant energy that can be found in the *electromagnetic spectrum* in the earth sciences, and the concept of ecological *niches* in biology. Students can do lab activities that involve these concepts, they can collect data, and describe patterns in the data. But these activities will not help them spontaneously generate the concepts mentioned above. It took scientists hundreds of years to develop these ideas, your students won't do it in a class period. Rather, these conceptual ideas need to be introduced through just-in-time instruction by the teacher.

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Here is another way to say this. The explanatory story that underlies your anchoring event for the unit will include unobservable processes, structures, and events. These will explain what *is* observable. Just-in-time instruction is about these unobservables. The unobservables might include features that are inaccessible (i.e. the layers of the earth or how the brain senses carbon dioxide levels in the blood), structures or processes that are too small to see (i.e. atomic structures, chemical bonding), or that are conceptual (i.e. selective pressure, the compression feature of sound waves, unbalanced forces).

Right away a caution is in order. You do *not* want to use direct instruction to create explanations for your students. Rather, you want students to know enough about a conceptual idea to then use it themselves to create explanations of phenomena you are studying. If we take the example of niches in biology for example, a teacher can describe what they are, why they are important, and how they work generally in ecosystems. But a teacher should not do all the reasoning for the students and give them exhaustive explanations of how niches function in ecosystems that the class is currently studying. This is the intellectual work you want students to do.

The goals of just-in-time instruction

• What you are aiming to do in this practice is to communicate conceptual ideas to students in a way that is meaningful, and that will allow the students to use these ideas to reason about a range of science phenomena.

• What this practice is *not*: Explaining the underlying causes of a natural phenomenon, with the intention that students will later reproduce this explanation.

How do I get started thinking about just-in-time instruction?

The best time to do just-in-time instruction is after you give students a brief exposure to materials or data and let them puzzle a bit. Then, if you have designed the experience well, students will realize that they need some new information or ideas in order to make progress. This is the time to then introduce the idea. These conceptual ideas can be introduced to students via combinations of readings, media, or presentations by the teacher. You should plan on no more than 10 minutes of time to do this.

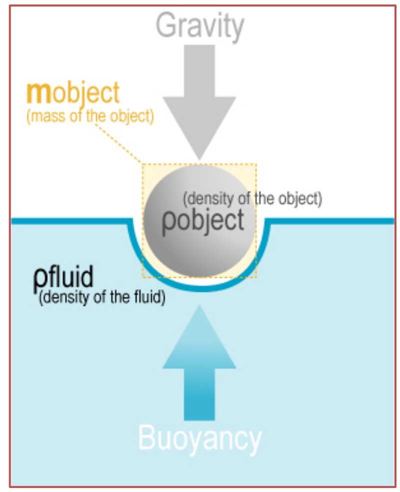
Following just-in-time instruction, students can "take the idea with them" into lab activities. They'll use the instructed *ideas to reason with* as they do the activity. You can encourage them to start using the new conceptual terms as they start to explain what they think is happening in a lab or when they start applying ideas from a lab to other natural phenomena. We do not want students to engage in activity simply to confirm an idea you have given them instruction on. It's a tricky balance.

Here's an example of the kinds of judgment you'd have to make. In middle school units on the phenomena of floating and sinking, students often puzzle about how materials that seem quite heavy can float in water (a ship) while things that are not so heavy (a ball of clay) will sink. A good teacher will recognize that when it comes to sinking and floating, the conceptual idea of density is helpful, but by itself it won't explain these puzzling events in ways that are sufficiently sophisticated for middle school students. At some point, the idea of buoyant forces have to be used to reason about objects that float or sink in water. But buoyant forces are still only part of the explanatory storyline. What's more is that these forces act in opposition to gravity. Here then, is the dilemma for the teacher. He is about to do a lab in which students are submerging masses underwater and predicting what they will weigh. The point is to help students understand that there are forces pulling down (gravity) but there are also forces directed upward on the mass (buoyant forces exerted by the water). The masses appears to weigh less under water.

So what ideas do students need in order for them to start reasoning about why this happens? The teacher has several choices. He could introduce:

A) a full explanation for the phenomenon they are about to collect data on
B) the idea of buoyant forces, meaning that that water exerts forces on objects that are floating or submerged
C) the idea of buoyancy AND that of unbalanced forces (when buoyant forces are greater than gravity an object will float).

The teacher decides on option B. Why? Because option A will actually prevent the students from doing any intellectual work—it's all being done by the teacher. He did not choose option C because he thought that during the activity he could choose questions to students that would get them to recognize gravity as the other force, and that it is the relationship between the two forces that determines whether objects sink or float. Option B appeared to be just enough for students to reason with—it would give them conceptual language to talk with one another about explanations for the phenomenon. The teacher further reasoned that in an upcoming lesson, these ideas of buoyant forces plus balanced and unbalanced forces could then be used to explain why a clay ball will sink, but that same ball when flattened into a "barge" will float. Not only does this teacher do just-in-time instruction, he also gives students just-enough-instruction, in terms of ideas to reason with.



Launching an episode of just-in-time instruction

Starting off on the right foot is important. Begin by communicating to students why they are being introduced to this idea. You can use the sentence frame below. As stated it sounds stiff and mechanical—don't say these exact words. This structure is just to cue you in as to what needs to be included in an introduction.

> Yesterday we were wrestling with [a puzzle, problem, idea, some new data], and several of you asked about [an idea, a relationship, a "what if" scenario]. These are good questions and you are referring to important ideas. If we don't understand this particular [problem, idea], we can't make progress in understanding [a key phenomenon or event that is anchoring your unit of instruction]. So I'd like to help you now with something called [use the conceptual term, use academic language]. Here is how I'd like you to use your science notebook in the next few minutes [describe how they can do something other than copy everything you say].

Things to think about during instruction

There is no recipe for doing the actual explanation during just-in-time instruction. There is, however, a number of pedagogical moves to consider using. There are also three kinds of resources you can share with students. These are: representations of the idea, analogies for the idea, or examples of the idea in action. You don't have to use all three. We've captured a range of helpful tips below in a list of "Do's" and "Don'ts." Each of the "Do's" below are helpful for all learners in understand what you are trying to communicate, but they are *particularly helpful* for English Language Learners and special needs students.

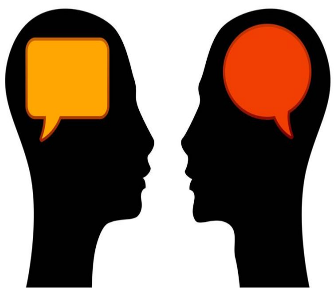
	Do's	Don'ts
Activating prior knowledge	Ask students to recall a pervious conversation or activity, or event that relates to the idea you are about to describe—"Remember when we did the lab on photosynthesis? Let's recall what happened there."	Don't dive right into the explanation without cueing the students' memory.
Choice of representations	Use multiple representations of the idea. These representations could be pictures, flow charts, diagrams, maps, math equations, chemical formulas or maps. It helps if one of them is not entirely symbolic or abstract (equations are most symbolic/abstract, for example, and picture are the least). Its important to help students see how key parts of one representation map onto the parallel parts of a second representation. This helps them make sense of both representations and make sense of the idea.	Don't rely on a single representation, especially if that representation is purely abstract/symbolic. Don't for example rely on chemical equations alone to talk about the idea of single replacement reactions.
Showing the representations	When you show the representations or example, tell students explicitly what they should pay attention to. For young learners, too many details in some representations (like images, maps, graphs) can distract and confuse them. If you are using presentation software, you can do a "progressive reveal" that starts with just the basic parts of a representation (like the X and Y axes of a graph), then add parts as students make sense of what is on the screen (like one set of data points at a time).	Don't speak about the whole representation at once, as if students know what to look for and how to analyze it.
Analogies	Think of appropriate analogies about the idea you are tying to explain ("air pressure is like a battle between molecules on the outside of a container and the molecules on the inside" OR "homeostasis that controls your body temperature operates like a thermostat in your house"). But do then explain why the analogy maps onto the actual event or process you are trying to explain.	Don't use analogies that will lead to misconceptions about the target phenomena that you are explaining. For example, describing heat as a fluid that flows from one place to another actually promotes

		misconceptions.
Use of examples	Use multiple examples of the idea in action. It helps if these examples are from events the students are familiar with through everyday experience (like breathing hard after a race) or commonly known to students (how volcanoes periodically erupt). The simpler and more straightforward the examples is, the better. Just as with using representations of the idea, avoid distracting details, help the student know what to pay attention to.	Don't use examples that are only accessible to kids of certain backgrounds, social classes, or ethnic groups. Not all your students have been to the beach or have flown in an airplane.
Use of vocabulary	Introduce only 3 or 4 academic terms, fewer is better. Be explicit about how the terms are derived—are there prefixes? What do they mean? What is the root of the word? Does the term have a root that is common to other words the students might be familiar with? You can invite student participation by having them identify other similar words.	Don't make your presentation about the memorization of vocabulary.
Involving students	Encourage students to offer examples of how the instructed idea might apply to situations they are familiar with themselves. Use the "turn and talk to your neighbor" as a way to lessen the risk of offering an example to the whole class.	Don't make the students into spectators.
Anticipate common alternative conceptions	Think ahead of time if the topic you are talking about is the subject of alternative conceptions. Be explicit and state the common misunderstanding to students and why that view is not scientific. This does not work very well to change their thinking (just telling them to think differently), but it is better than not addressing their thinking at all.	Don't think that students come to the discussion as blank slates.

Invite participation by students in the thinking

You should check early in the presentation if students understand the first couple of things you've said. If you don't check and the students don't understand, they will be frustrated when you build on those ideas and they really get lost. They'll resort to memorization. Use "turn and talk to your neighbor" and ask students to come up with an example of some idea you've just mentioned, or ask how two parts of an idea are related, or ask for a prediction based on the idea. You can also offer a thought experiment, "What would happen if…" Please don't ask I-R-E questions.

How to express ideas clearly and unambiguously—(how it helps English Language Learners in particular)



In terms of verbal expression, keep these things in mind. Remember that communicating clearly about academic ideas is an unnatural way of talking. You have to really think about *how* you are talking, not just what you are talking about.

Just like the table above, these moves are helpful for all learners in understand what you are trying to communicate, but they are *particularly helpful* for English Language Learners and special needs students.

• Use simple sentences that are expressed in active voice (stating the subject, verb, then object of the action), rather than passive voice (object of action, verb, subject). Example of active voice: "The sun (subject) releases (verb) different types of radiant energy (object) from it's surface." Here is the passive voice: "Different types of radiant energy (object) are released (verb) by the sun (subject)."

• Don't use long "wind-ups" to begin your sentences. Here's an example: "Because scientists have quite a few kinds of sensitive instruments that are orbiting the earth on satellites (←everything previous to this is the wind-up), we know that the sun gives off different types of radiant energy from its surface."

• Related to wind-ups are "asides" that are inserted in the middle of sentences. These are super distracting, especially to those whose first language is not English. Here is an example: "The sun, which is just an average size star and about halfway through it's life cycle, gives of different types of radiant energy."

• Don't over-use pronouns—students don't know what these refer to. Here's an example: "It gives off a lot of radiant energy." If a teacher says this, students will wonder: "What is 'it'?" This sentence was referring to the sun giving off radiant energy, but who would know that? Here is a list of pronouns, use them only sparingly (it, them, they, those, she, her him, his).

• Use your teacher voice, meaning assertive and clearly audible throughout the room. Here's tip from the martial arts—let there be no trace of self-consciousness in your voice. That's the difference in how a veteran talks and a beginner talks. Walk around the room as you speak. Don't hide behind the desk.

• Use hand gestures if you like, but use ones that match exactly what you are saying. They can be effective.

• Don't write random thoughts on the board unless you are going to do something organized with them or if you are going to add to a list.

Miscellaneous

Many of the basic principles for this practice can apply also to presentations in which you are modeling a skill (such as graphing, using a microscope, or interpreting a topographical map), or even modeling a scientific practice (such as designing an experiment, critiquing a scientific model, or arguing with evidence).

Summarize at the end

At the end of the presentation, summarize what the explanation actually explains. What are the key words to remember? What are the key relationships? What is the key analogy, model, or metaphor to remember?

Don't ask "Who has questions?" That is jut an invitation to clam up. Invite questions instead, by offering a sentence frame for them to fill in: I think I understand ________, but am still puzzled by _______. This can be done via exit slip as well.

And finally, tell the students that you don't expect them to fully understand the idea and that you are just introducing it now. They will have gaps in their understanding and that is ok because this is not the only time we'll talk about and use this idea. In fact we will be using this idea to better understand the following activity.

Note to reader: this paper is still a work in progress! It is a draft, and will be updated soon. Hence the lack of an ending to this otherwise passable document.