Five Guidelines

Ways to support improvement at thinking / acting like an "expert".

These guidelines are for students to help them improve their abilities to work with scientific information. Instructors can foster their use, or demonstrate them, during lectures or class activities.

Remember that this will be the only science course taken by the majority of students. Therefore we can have only limited expectations for students becoming more expert-like in their thinking. However, it is probably worth while highlighting when students are "automatically" using such thinking styles. This shows them they can, and do, think appropriately when given suitable opportunities.

1. Experts are good at using a **framework or structure** for their knowledge. Try to fit all your learning into a framework identified by instructors, or your own. For example, think: "Are we talking about observations or explanations? Are we speculating? Must we decide based on likelihood or certainty? And so on.

2. Ideally the learning goals should be based on some explicit framework, and using that framework should be articulated as part of the learning goals.

3. Behaviors that help when working with scientific information
    a. Be willing to try things that might fail, because you can advance your learning by analyzing why/how you failed. Progress was never made by getting it "right" all the time!
    b. Information makes more sense if you place it within a broader context.
    c. "Brainstorming" with colleagues is a powerful tool for refining ideas and understanding.
    d. Aspects of dealing with problems / issues:
    1) identify the issue, or state the problem; 2) list what you need to know; 3) find commonalities.
    e. Look for meaningful patterns of information.

4. Numbers and values
    a. Use common metrics.
    b. In physical sciences, the metric "value" always includes numbers and units.
    c. Dimensions (units) give information about relationships.

5. Common "standard practices":
    a. Some phenomena must satisfy budgets (such as a heat budget). Budgets can help you anticipate the constraints on a system.
    b. Equations are just a shorthand notation for concepts we can describe in words. They are like the sheet-music of science.
    c. The limits, boundaries, or edges of a concept help define and constrain it ... and help you understand it.
    d. Organize your knowledge to aid deep understanding.

6. All instructors should feel free to point out additional in-class experiences (for example while working on clicker questions) during which students are given opportunities to use "expert thinking". Highlight these with the "Insights" icon (light bulb), but it is probably better to avoid the term "expert thinking".

Some pedagogic principles (Ask an STLF for references.)

1. The brain cannot be simply "filled" – learning happens as result of **working** the brain.
2. Cognitive overload will prevent learning. One new concept every 10-15 minutes is plenty.
3. Motivation is key. No motivation = no learning, regardless of all other aspects.
4. Keep in mind both intrinsic vs. extrinsic (eg. self vs. grades oriented) motivation.
5. Prior learning is crucial, sometimes called foundational knowledge. No person has "no prior knowledge". AND, misconceptions must be found, otherwise further errors in understanding will result.
6. Provide frameworks to help with construction of knowledge.
7. Active effort is crucial. Passive behavior produced very limited results.
8. Students must apply effort related to the concept – simply hearing about 4-5 new complex concepts during 50 minutes of passive sitting does not support learning.
9. Feedback is crucial. Students cannot try harder or differently without help with identifying what's working and when they are off track. They will get better as their education progresses – but it doesn't come instantly!
10. Good study habits must be learned and can be taught. Many students in eosc114 are only 18 years old and have no idea what is needed to succeed at university.
11. Learning is essentially a social activity. However, supporting "groups" or "teams" in classes is non-trivial.
12. Developing "transfer skills" (ability to apply in new contexts) is challenging.
13. Target all levels (consider Bloom's taxonomy) and domains of learning (cognitive, skills, attitude - consider "heads, hands, hearts").
14. http://www.cwsei.ubc.ca/resources/index.html has many evidence-based pointers about teaching and learning.
15. No pedagogic strategies are trivial nor the answer to all problems. It is possible to do more harm than good if a "great idea" is tried without doing it right. Ask for wisdom from colleagues or teach/learn support staff.

Some Lecture Guidelines

These are neither comprehensive nor complete. They are a starting point. Please make use of EOS-SEI teaching and learning fellows to test-run lecture sequences, clicker questions, homework, exam and other questioning issues.

1. **Appendix IV** contains some "best practices" for using PowerPoint.

2. Provide reminders of goals / structure / framework frequently. HOWEVER, don't waste lots of time summarizing in detail at the end of each lecture period – students "tune out" if you dwell on these.

3. Remember "cognitive overload". Give students opportunities to USE new ideas frequently (eg clicker questions) but make sure you include some form of feedback so students aren't "using" ideas blindly.

4. Where ever possible, try to relate current topics with content & activities in <u>other</u> modules. That means you have to know what is being discussed in the other modules! So please communicate with all other members of this course's teaching team.

5. As much as possible, try to avoid seeming distant and removed from students.
    a. Most students sit in back half of a large lecture theater.
    b. Use the microphone and instructor's clicker so you can wander around the lecture theater as you talk.
    c. If you ask open questions, count slowly to 10 before refining the question. But do not just answer the question. No one will ever choose to respond again because they know you will answer for them.
    d. Ask occasional quick "show of hands" types of questions – something quicker than a clicker question. One format that works is *"If I asked an exam question about xyz, how many would <u>not</u> be confident about …"*. This is easier for students to answer honestly than "Does everyone understand?", which nearly always results in blank stares.
    e. Consider starting the class period with "Any pressing questions?"
    f. Watch for unsolicited questions (hands up) and respect them.

6. A good questioning paradigm is to ask "what do you **perceive** about ... this video/image/graph?" some options for using clickers with such a question are: "How many *xyz* do you perceive?" or "How often do you see *xyz* happen?" or "What happened when *xyz* ?"; all with multiple choice options.

7. Do not ask "trick" questions which distract the attention from the main point.

8. Use lots of video
    a. Search and use Youtube.
    b. Include several per lecture.
    c. Include some no-stress questions.

   d. IMPORTANT: students need to have a stake in what's shown. Make them predict, take sides, whatever.
   e. For a useful form of followup question, see "A good questioning paradigm is …." above.

9. **More on videos:** Having students commit to a judgment **prior** to seeing a video or demonstration helps motivate them, and directs attention towards the key concept in the video or demo. Therefore consider using a pre-post question pair to get students to commit individually to a decision or choice before the video or demonstration. Show the responses to the initial question but DO NOT discuss yet. Show the video. After it's over, ask the question again (or something similar or related). Discuss results or have peers discuss. This pattern is based on research about what makes demonstrations beneficial. Simply showing a demonstration or video is usually only useful as entertainment. It's all about motivation, commitment, well-directed thinking, and assessment that helps make learning happen.

10. As noted above, ask an STLF for input or feedback. Having someone visit a class and provide observational feedback on how the lesson went, how the clicker questions worked, or other aspects of the class is always very useful regardless of your experience and confidence (or lack thereof!)

11. **What about providing "extra material"?** If it is important, learning goals must say so. Then, the concepts must be assessed, otherwise students will not treat it as important. THEREFORE, do not include extra content with the necessary material. You could include pointers and references, but you should put material that is *supplemental and therefore not assessed* into a separate place.

Some "best practices" for using PowerPoint.

Modified from http://www.turpincommunication.com/articles/pptbestpractices.htm

Tips on **developing** PowerPoint presentations

- **How many slides?** 1 per minute is too fast. Therefore: for a 50 min. lecture, 4 mins for setup/close out + ~4 for video + 4 clicker questions x avg 3 minutes each = ~15 slides. Or, consider ~30 as the absolute maximum if you include an opening slide, goals or topics lists, and if your slides are very sparse.
  (Note that 3 mins for each clicker question should be **average**. "Easy" clickers are faster (but less useful); more involved ones with peer discussion and pre-post, etc., will be slower.)
- **How much on each slide?** No more than one thought, unless they are content lists. Sparse is good. Very sparse means more slides – just remember you should only be spending less than 30 minutes actually referring to slides. The rest of the time students should be actively involved in some way.
- It is not bad to include slides with introduction, closing remarks, and intermediate reminders of goals or outlines. HOWEVER don't dwell on these – students tune out when they show up. But seeing them helps communicate a sense of structure to the material.
- Treat the heading of each slide as valuable real estate. Make your headings specific and meaningful.
- The smallest letters on any slide should be at least 24 points.
- Slides always look better on your computer than they do on when projected. Some pointers are: i) Avoid subtle colors. ii) Always increase brightness of photographs. iii) Do not rely on color to make a point. iv) Recall that 7-10% of males are red/green color blind (http://en.wikipedia.org/wiki/Color_blind).
- Avoid graphics that are NOT related to the message. This includes textured backgrounds.
- Try to ensure that print versions are equally readable.
- Less is more. Use single words or phrases rather than sentences or paragraphs. Your bullet points are there to remind you what to talk about, not tell the whole story.
- As you mercilessly edit your slides, cutting away every word that is not absolutely necessary, say to yourself, "My slides are not a *script*. I will not read my slides. My slides are not a script."

Tips on **delivering** PowerPoint presentations

- Take the time to set up each slide. Your explanation of a slide should begin with an overview. Tell people what they are looking at—even if you think it's obvious, even if it's a list of bullet points. BUT don't just read them.
- Pause before moving to a next slide. You might feel awkward, but you will sound great.
- Look at the slide when you want your listeners to look at it. Look at your listeners when you want to draw their attention away from the slide.
- Use the whole room – walk around, use a remote slide advancer and pointer if you can. Try to reduce the "barrier" between you and the students.
- As you deliver your presentation, especially when you're deep into the body, assume that your listeners are thinking, "What does this have to do with me?" or "Why should I care?" This will remind you to keep your explanations short and relevant.
- Visual aids in your presentation are meant to back you up as you engage your audience in a structured conversation.

Regarding new terms and scientific jargon

Adapted from C. Wieman, February 26, 2008:

"I spent a couple of days trying to find answers to questions about learning technical jargon a couple of years ago. **The quick answer is that I could not find anything**! I am convinced that this is a major unexplored area for science education research. From research of my own group and others, I am convinced that the technical language is a major impediment to the learning of science {ed- especially when the "technical jargon" involves normal words that have been given new meanings by the experts. All disciplines have this problem.}

Finding no research on the subject, I asked **John Bransford (of How People Learn)** what he could tell me. He did some early work on language. He sent me a long reply, but brief summary was he did not know of research on learning technical jargon, but **some basic things about learning languages likely apply. Namely, to learn jargon, students have to practice using it in authentic discourse repeatedly and regularly, just as they would learn a foreign language**. It also would likely help them learn if they had to explicitly explain what the terms meant in their own words, perhaps to a younger sibling for example.

Also, I am confident that **cognitive load issues** are highly relevant to use of jargon. In other words, every new jargon term that is introduced in a class period will demand a heavy price in terms of thinking and "brain space". **For each new term, there will be roughly 14% less working memory available for student to use to learn anything else in that class.** So you can be pretty confident that instructors should avoid introducing any jargon in lecture that is not ABSOLUTELY necessary. The cognitive load demands mean that any course that is introducing a lot of technical terminology effectively becomes a terminology course, whether you like it or not. There is just not enough brain left to learn anything else. This is why I advocate that any time you are establishing learning goals for a course, the **technical terms you want students to know are listed as explicit goals**. That helps one focus on what terms are essential and have to be covered, and implicitly also identifies which are not essential, and hence should not be used. You can also be pretty confident that **any jargon that is introduced to students, but they will not be called upon to use regularly after the course is over, they will very quickly forget**. So there is a very real waste of time and energy in using a nonessential jargon term. Students will not retain it, and it will reduce what they learn.

So in a course like eosc114 where the students will not be using terminology from that course in a subsequent course, I would advocate actually not introducing ANY jargon. In a class where there is jargon that you want students to learn, I suggest having them review and have to answer some questions about the terms before coming to class. I have not done any research proving this works, but it seems likely that it will reduce the cognitive load when the term is used in lecture.

Carl.

P.S. I should have added that, although I never gathered quantitative data on it, when we started using clicker questions where students had to discuss with each other, their facility with the language of physics dramatically improved. In retrospect, it should have been obvious that this would happen.