

In the block below list one criterion/ characteristic you would expect to find in an effective lesson. Now discuss this with a colleague. Finally decide on a criterion that you and your colleague consider to be the most important for an effective lesson. Get ready to share.

**ELEMENTS OF EFFECTIVE INSTRUCTION FOR EFFECTIVE LESSONS**

**(*How People Learn*, 2003; *How Students Learn: Science in the Classroom,* 2005)**

* **Motivation:** 
  + However well-designed the instruction, students are unlikely to learn if they do not have a desire to do so. Instruction needs to “hook” students by addressing something they have wondered about, or can be induced to wonder about, possibly, but not necessarily, in a real-world context.
* **Eliciting Students’ Prior Knowledge:**
  + Research has shown convincingly that students do not come to school as empty vessels; rather, they come with ideas they have gleaned from books, TV, movies, and real-life experiences. These ideas may either facilitate or impede their learning of important ideas in science. There is considerable evidence that instruction is most effective when it elicits students’ initial ideas, provides them with opportunities to confront those ideas, helps them formulate new ideas based on the evidence, and encourages them to reflect upon how their ideas have evolved.
* **Intellectual Engagement:** 
  + Research on learning suggests that the hallmark of effective lessons is that they include meaningful experiences that engage students intellectually with important science content. Lessons need to engage students in doing the intellectual work, and make sure that the intellectual work is focused on the learning goal.
* **Use of Evidence to Make and Critique Claims:**
  + Being scientifically literate requires understanding both scientific ideas and the nature of the scientific enterprise. Students should be encouraged to view science as a process by which knowledge is constructed, not as a collection of facts. An integral part of the scientific process is the collection and interpretation of data, which is then used to critique claims and see if they are supported by the evidence.
* **Sense-Making:**
  + Effective science instruction requires opportunities for students to make sense of the ideas with which they have been engaged: (a) Making connections between what they did in a lesson and what they were intended to learn. (b )Connecting the new ideas to knowledge that students already have, placing the lesson’s learning goals in a larger scientific framework and helping students organize their knowledge.

**Components in Detail**

**Motivation**

There are two categories of ways students can be motivated: extrinsic motivation and intrinsic motivation. Extrinsic motivation is familiar to most of us, and includes deadlines and tests. Having students interact with real-world phenomena can be very motivating (intrinsically), whether that interaction is through a hands-on experiment, a computer simulation, a teacher-led demonstration, or a whole class discussion. There is some evidence that extrinsic motivation may actually be detrimental, impeding students’ intrinsic desire to learn. For example, students doing a research project may focus on completing the task rather than learning the concepts (Moje et al., 2001; Nuthall, 1999, 2001). Extrinsic motivation can also stifle natural curiosity, so intrinsic motivation whenever possible appears to be a better bet.

**Eliciting Students’ Prior Knowledge**

Like motivation, elicitation of prior knowledge can happen in different ways. One key feature is that the elicitation focuses on the targeted concepts. For example, when teaching about factors that plants need to be healthy, asking students a general question like, “What do you know about plants?” is unlikely to be as useful as a specific prompt like, “What do plants need to stay healthy? Why do you think each is necessary?” Second, it is important that the teacher not judge initial ideas for correctness during the elicitation, but rather provide students with learning experiences that enable them to refine their initial ideas. Cognitive change will be fostered by confronting incorrect or incomplete ideas with evidence that conflicts with the initial ideas. In many cases, simply telling students the right answer is unlikely to lead to long term changes in their thinking.

**Intellectual Engagement**

Intellectual engagement doesn’t have to be through a hands-on activity; in fact, quite a few hands-on activities don’t intellectually engage students (“activity for activity’s sake”). Students can be intellectually engaged by having interesting questions posed such as, “Does the earth go around the sun, or the sun goes around the earth? How do we know?” Students can also be intellectually engaged by considering examples from their every-day lives, examples that can serve as evidence for drawing or critiquing a conclusion. For example, when learning about potential and kinetic energy and conservation of energy, student experiences with roller coasters can serve as data: when you’re just starting at the top of the roller coaster, you’re not moving; but with just a little push to get you over the hump, you start to go faster and faster (with maximum speed at the bottom). Then when you start climbing again, the speed of the coaster decreases. In any case, it’s important that the students are the ones doing the intellectual work and that teachers don’t short-circuit the learning by doing the thinking for them.

**Use of Evidence to Make and Critique Claims**

Drawing conclusions from evidence requires teachers to be very deliberate in guiding student learning. Instruction (including laboratory experiences and lectures/discussions) needs to be very carefully designed so that students will engage with data that will allow them to draw appropriate conclusions. (If an experiment does not adequately control variables, is prone to large measurement error, or is otherwise likely to yield flawed data, students may draw conclusions that are supported by their data, but aren’t consistent with the best scientific evidence.) For example, a group of students was trying to test the effect of light on plant growth, and decided to place one plant in a dark closet and another on a very bright window sill. After one week, the students observed that the plant in the closet was taller than the one on the window sill, and concluded that plants grow better in the dark. [Plants actually grow “better,” i.e., are more healthy, in light. In this example, the plant in the dark grew taller (though with fewer branches/leaves and less coloration) due to etiolation, a mechanism that increases the probability a plant will reach a source of light. Over a longer period of time, a plant grown in the absence of light will not survive, but because “better” was not well-defined in the experiment, and the experiment was not conducted over a long enough period of time, students drew a conclusion from their data that is inconsistent with current scientific understanding. Using evidence to draw conclusions requires students to agree on the validity of the data. It’s important that any conflicting data be resolved, either through conducting additional trials/experiments or by consideration of scientific uncertainty. For example, in a lesson intended to teach students what a complete circuit is, the teacher had students test different configurations of a light bulb, battery, and a wire. For each configuration, students were asked to draw a picture of what they tested and record whether the bulb lit or not. Students then posted their drawings on the wall in the “it works” or “it didn’t work” section. During the discussion, students disagreed about whether some of the configurations did or did not work. Thus, before asking students to look for patterns of what works and what doesn’t work, the teacher asked students to re-test the configurations in question so that the entire class would be in agreement and analyzing the same data. For example, it generally is not feasible for students to gather the data necessary to show that Earth orbits the Sun. However, a teacher can describe what the data were that led the scientific community to shift from a geocentric to a heliocentric view of the solar system (e.g., the varying time it took for the Sun to traverse the sky over the course of a year and the retrograde motion of planets).

**Sense-Making**

Common ways sense-making is done include whole class discussion, written reflections on what students learned from instruction/how their thinking has changed, and the application of ideas to new contexts. For example, the teacher may have students revisit their responses to the elicitation task and write a description of how their thinking has changed and why they changed their mind. Applying new knowledge to novel contexts is likely to be the most challenging form of sense-making for students. For example, after a series of lessons on adaptation that examined several *plant* species, students may be asked to apply what they have learned by describing how the physical features and/or behaviors of a particular *animal* species provide that species with an advantage. The important consideration in all types of sense-making is that the idea students are making sense of is both developmentally appropriate and on the trajectory toward the accepted scientific ideas.

**The Learning Cycle as a Tool for Planning Science**

**Instruction**

The learning cycle is an established planning method in science education and consistent with contemporary theories about how individuals learn. It is easy to learn and useful in creating opportunities to learn science. You can think of the learning cycle model as having five parts, though these parts are not discrete or linear.

***Engage***: In most instances you will want to begin with Engage. In this stage you want to create interest and generate curiosity in the topic of study; raise questions and elicit responses from students that will give you an idea of what they already know. This is also a good opportunity for you to identify misconceptions in students' understanding. During this stage students should be asking questions (Why did this happen? How can I find out?) Examples of engaging activities include the use of children's literature and discrepant events.

***Explore***: During the Explore stage students should be given opportunities to work together without direct instruction from the teacher. You should act as a facilitator helping students to frame questions by asking questions and observing. Using Piaget's theory, this is the time for disequilibrium. Students should be puzzled. This is the opportunity for students to test predictions and hypotheses and/or form new ones, try alternatives and discuss them with peers, record observations and ideas and suspend judgment.

***Explain***: During Explain, you should encourage students to explain concepts in their own words, ask for evidence and clarification of their explanation, listen critically to one another's explanation and those of the teacher. Students should use observations and recordings in their explanations. At this stage you should provide definitions and explanations using students' previous experiences as a basis for this discussion.

***Extend:*** During Extend students should apply concepts and skills in new (but similar) situations and use formal labels and definitions. Remind students of alternative explanations and to consider existing data and evidence as they explore new situations.

Explore strategies apply here as well because students should be using the previous information to ask questions, propose solutions, make decisions, experiment, and record observations.

***Evaluate***: Evaluation should take place throughout the learning experience. You should observe students' knowledge and/or skills, application of new concepts and a change in thinking. Students should assess their own learning. Ask open-ended questions and look for answers that use observation, evidence, and previously accepted explanations. Ask questions that would encourage future investigations.

***(Reference Source: Anthony W. Lorsbach at http://www.coe.ilstu.edu/scienceed/lorsbach/257lrcy.htm )***

**POSSIBLE WAYS FOR INCORPORATING ENGINEERING ACTIVITIES INTO YOUR CLASSROOM; BRAINSTORM**

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**Pre-Lesson Planning:**

**You have learned thus far some basics regarding kite and/ or bridge building. Brainstorm at least one major science/ math concept that one would cover in learning about the designs of kites and bridges: (ex: Force)**

**Ask yourself, where and at what time of the year, in your curriculum is such a concept covered (ex: in the Fall)**

**Now design an *assessment based* *content* objective (s) (this means you are sure that your students will accomplish this because you have a means to assess them on this) (ex: Students will be able to identify and name the various forces acting on an object not in motion)**

**Does this cover your state and national content standards? (Check your standards both state and national; make sure that your objectives follow these)**

**Lesson Plan**

**Using the I-B-C outline as well as incorporating the effective lesson components previously mentioned, try to design an inquiry based lesson that targets, or includes, the objective you have listed and centers around the use of the experience you have learned in the design of bridges and kites. At this point, you will need to brainstorm and prep this for the final session.**

**I-B-C OUTLINE**

Questions to Think About While Planning

Topic Title (What is my topic about?)

Thematic Question: (What *interesting* question can I generate that will catch my student’s attention. Hint: Look at real life examples)

Grade level: (Is the topic and question appropriate for this grade level/ age group?)

Estimated Lesson Time/ Materials: (How long will I want the students to work on this thematic question? What materials/ resources/ references will they need?)

Standards addressed: (What *national and state content* standards are considered)

Assessment Based Objectives:(What will I be assessing them on? List these in bullet format making them *possible* to achieve)

Implementing the Lesson

Introduction (i.e. How will I start the lesson?):

* What question will you ask to generate students’ prior concepts?-Will you show them a visual(s) that will generate questions? If so what will it be?
* What question(s) will you have them focus on?
* Will you have them generate their own questions? If so then use discussion to bring them back to the thematic question you want them to follow through.

Body (i.e. What hands on/ minds on activity will they do to target the required objective? Focus on making the activity an investigative one where students observe and measure various variables, document their observations and then discuss their findings with their group and then the whole class. Remember to assess them on their content and skills)

Conclusion: (i.e. What did the students learn? Focus on reminding students what they did in this lesson and why they did it. Have them show you or discuss what they have learned. This can also be in the form of a mini-activity at the end that helps give you an idea of what they *did* learn in the lesson. You can go further in your conclusion by showing connections to real life examples and making extension questions that can be used to introduce the upcoming lesson)

**IBC**

**POSSIBLE LESSON INCORPORATION STRATEGY (IN BRIEF)**

* **(I)-Introduction :**
  + Motivate
  + Intrigue
  + Generate Curiosity
  + Generate prior perceptions of concepts
  + Tools:
    - Discrepant events
    - Thought questions-(ex: Are steel bridges better than wooden ones?)
* **(B)-Body** 
  + Lecture/ Authentic Activities
  + Hands on/ Minds on
  + Depending on time – revolves around 2 or more objectives (# should increase as age group increases)
  + Objectives MUST be based on YOUR assessment (refer to content knowledge emphasized on standardized tests; Focus on test- represented content not the items on tests i.e. the big ideas in science where the national and state standards originate from.- check NSES, NSTA for these:
    - (See <http://www.nap.edu/openbook.php?record_id=4962>)
    - (See <http://www.nsta.org/>)
* **(C)-Conclusion** 
  + *Can* have a summative lesson assessment that restates the outcomes in question format such as those on NJASK, HSPA
  + *Should* include either formal or informal assessment of students knowledge
  + *Should* summarize what was learned with an emphasis on the targeted content outcomes (standardized based objectives)
  + *Should* connect to the next lesson- can do this by the conclusion being a part of the introduction for the next lesson and an extension that students will need to think about before they experience the next lesson

**Cited References**

**National Research Council. (2003). *How people learn: Brain, mind, experience, and school.* J. D. Bransford, A. L. Brown, & R. R. Cocking (Eds.). Washington, DC: National Academy Press.**

**National Research Council. (2005). *How students learn: Science in the classroom.* M. S. Donovan & J. D. Bransford, (Eds.) Washington, DC: National Academy Press.**

**Noteworthy References**

**Moje, E. B., Collazo, T., Carrillo, R., & Marx, R. W. (2001). “Maestro, what is ‘quality’?”: Language, literacy, and discourse in project-based science. *Journal of Research in Science Teaching*, *38*, 469-498.**

**Nuthall, G. (1999). The way students learn: Acquiring knowledge from an integrated science and social studies unit. *The Elementary School Journal*, *99*(4), 303-341.**

**Nuthall, G. (2001). Understanding how classroom experience shapes students’ minds. *Unterrichts Wissenschaft*, *29*(3), 224-267.**

**Weiss, I.R., Pasley, J. D., Smith, P. S., Banilower, E. R., & Heck, D. J. (2003). *Looking inside the classroom: A study of K-12 mathematics and science education in the United States.* Chapel Hill, NC: Horizon Research, Inc.**

**Helpful Online References**

[**http://www.nsf.gov/news/classroom/engineering.jsp**](http://www.nsf.gov/news/classroom/engineering.jsp) **National Science Foundation - Engineering classroom resources.**

[**www.nsdl.org**](http://www.nsf.gov/cgi-bin/good-bye?http://www.nsdl.org)  **National Science Digital Library**

[**http://teachengineering.org/**](http://teachengineering.org/) **Various samples across grade levels**

[**http://blogs.asee.org/goengineering/engineering-in-the-classroom/**](http://blogs.asee.org/goengineering/engineering-in-the-classroom/) **Making cars K-2**

[**http://science- ed.pnl.gov/teachers/fossils.stm**](http://science-ed.pnl.gov/teachers/fossils.stm) **Department of Energy- Fossils 4-8**