A study of over 300 inquiry activities recommends eight models for the classroom

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Creating inquiry activities is inherently difficult (Meyer et al. 2011; Meyer and Avery 2010). Asking meaningful questions requires both background knowledge on the part of the students and complexity on the part of the phenomena. Yet numerous strategies can help teachers conduct inquiry activities. In this article, we share a taxonomy of teaching strategies used to create inquiry activities in K–12 classrooms. In our research (Meyer et al. 2012a, 2012b), we reviewed over 300 activities from a variety of curriculum resources and identified eight common strategies available to classroom teachers and other instructional planners.
Protocols

A protocol is a well-defined procedure for collecting data. It may seem similar to a traditional cookbook lab, but a protocol is treated as a tool rather than as the entire lab experience. A protocol can be applied to a variety of situations, not just the one for which it is introduced and learned. (Some cookbook labs can be adapted to form protocols, but others cannot.) Students who learn a protocol in an initial circumstance can apply it to further research that is more varied and student directed.

For example, in the lettuce seed bioassay (Trautmann 2001), students are given directions for producing a serial dilution of a salt solution, setting up a bioassay using lettuce seeds, and evaluating the results to determine the effect of salt concentration on seed germination and growth. Once students have had that experience, they can engage in further, more varied research, investigating other concentration ranges, other toxins, and even other biological indicators. At the most sophisticated end of the spectrum, the bioassay can become part of a larger, extensive research endeavor, such as examining the impact of road development on the environment.

Learning a protocol, then, offers more than a new technical skill. It introduces the student to an entire way of looking at the natural world. The data set produced in the initial learning round may also suggest what to investigate next, just as with science at large. Hence the student has been brought on board the knowledge development cycle.

Design challenge

Design challenge activities center around an explicit task to produce a product. The details of the assignment are critical to making the design challenge an effective inquiry rather than the equivalent of a cookbook lab (Meyer 2012). The assigned task and associated constraints must create tension without a clear-cut resolution. While many inquiry activities benefit from being more open-ended, design challenges benefit from being over constrained.

The design task should require students to acquire certain knowledge bases needed for the design challenge. Even when this knowledge is learned in more traditional manners, it is done so in the context of needing it for the challenge. Some activities use a jigsaw arrangement, where students divide into specialty groups to learn different knowledge bases then form design teams made up of representatives of each specialty group.

A common example of a design challenge is bridge building. Students must devise a structure to hold as much mass as possible without breaking. Various constraints can be imposed, such as limiting the amount and type of materials used or challenging students to maximize the ratio of mass held to mass of the structure itself.

Product testing

In product testing activities, students evaluate and compare performance. They must devise and implement ways to consistently compare items and, often, to quantify those comparisons. This means recreating a phenomenon in a controlled, reproducible, and measurable manner. This challenge often breaks down into three parts.

- Determining a product’s desired attributes.
- Devising ways of consistently testing those attributes.
- Determining how to integrate the results to reach a conclusion.
Black boxes

Black box activities challenge students to determine the nature of things hidden from view. Students must form logical arguments so they can reach conclusions without direct observations.

Black box activities can be designed to highlight various concepts, such as the difference between observation and inference. For example, the simplest black box activity is one in which students are challenged to determine what objects are inside an actual closed box. Black box activities aren’t merely puzzles with one acceptable solution. Rather, the ambiguous “black box” quality of the inquiry means that the argument about the conclusion is even more essential than the conclusion itself.

Black boxes can also be used to make more specific connections to atomic theory. They illustrate the ability to reach conclusions despite a lack of direct observation. For example, students can be challenged to determine the size and shape of objects hidden from view by probing the objects with marbles or other small balls. This would be analogous to the Rutherford alpha particle experiment and other particle scattering experiments. Other black boxes can be devised where some observations also change the object, hence simulating the Heisenberg Uncertainty Principle. A typical instance of this uses a closed box pierced by dowels, on which washers have been placed. Removing a dowel gives information about the washers’ location but also changes the object.

Finally, students determine how to weigh the results to choose the best brand.

In a sense, the product testing model of inquiry is the inverse of the protocol and design challenge models: Rather than finding situations in which to apply an existing protocol, students create a protocol to evaluate a given situation; and rather than creating a product that meets certain criteria, students create the criteria to assess given products.
Intrinsic data space

Intrinsic data space activities immerse students in a data space that inherently implies a question. These activities have a “sandbox” aspect that allows for easy exploration of the data and creates a meaningful inquiry experience by posing a natural challenge.

An example is Mystery Bones (Slesnick 1985). Students are given cutouts of bone fossils. The natural and obvious task that presents itself is arranging the bones into possible animal forms. Students can be further challenged to make conclusions about the nature of the animals they form, extending the activity beyond the natural appeal of the data.

Simulated environments would be an important subcategory of intrinsic data space activities. Computer programs such as Interactive Physics or Stella (see “On the web”) can allow students the flexibility and freedom to explore while lowering the technical and cognitive barriers.

Discrepant event

Discrepant event activities center on a distinct, non-intuitive, surprising, and often impressive event and naturally poses the question “What is going on?”

The ammonia fountain (Shakhashiri 1989) is an example of the discrepant event model. Here, students see water rise up a tube and turn into a pink fountain, challenging students to explain the surprising result. The non-intuitive aspect is crucial, helping to make the question to students both meaningful and non-trivial. And it provides opportunities for students to stake out different explanations. However, an effective activity requires that the students experience the phenomena as discrepant, a quality dependent on the context and the students. What is obviously problematic for one set of students might not be for another.

Many discrepant event activities are done as teacher-led demonstrations, for technical or safety reasons. However, they also illustrate how an otherwise teacher-centered activity (the teacher is in control and doing the physical work of the activity) can be executed in an inquiry manner.

And like the protocol model, the discrepant event model provides a possible opportunity for turning traditional cookbook labs into inquiry activities.

Taxonomy

Taxonomy activities present students with a wide variety of samples. Students are then challenged to create a meaningful organization of the samples. A sufficient number and variety of samples is important, so that the exercise is not reduced to students simply finding predetermined categories. Likewise, students need sufficient context to both motivate the formation of organization and to guide decisions as to what aspects of the samples matter over others. Since there is more than one way to categorize the samples, arguments about the categories become an essential part of the inquiry.

Taxonomy activities are a clear part of biology courses but do not need to be limited to this. For example, as part of an astronomy unit, students can be challenged to form a categorization of celestial objects. Students would be given a variety of data on a variety of objects, without names to create preconceived notions. Similarly, chemistry students can be presented with a large list of reactions and challenged to define groups.

Modeling

While modeling is a broad concept in science education, our definition here is narrower. In modeling activities, students are challenged to construct a functioning model of a natural phenomenon, though not necessarily a physical model. Stella, for example, is a computer modeling program widely used in education (see “On the web”). Modeling is useful when the phenomena being modeled—for example, an
The mystery tube (National Academy of Sciences 1998) exercise presents students with a tube containing various ropes. Pulling on a rope may (or may not) affect the other ropes. Students are challenged to create a tube of their own that mimics the behavior of the target tube, hence modeling the phenomenon. Since the inside of the new model can be directly observed, and the model behaves like the original, arguments can be made for the nature of the original tube.

**Combinations and overlaps**

These activity structures aren’t necessarily distinct. Certain inquiry activities might combine or overlap the different categories. For example, consider an activity intended to teach about erosion by giving students the design challenge of designing a monument that will resist erosion. Preparation for accomplishing the larger design challenge can include developing an understanding of the factors involved through a series of mini-protocols. In other cases, the same phenomena can be approached using different activity structures. For example, simple paper helicopters can be made whose performance varies according to several parameters (Exploratorium 1997). Students can investigate this performance in different ways. Asking students to determine how flight time relates to release height would form a protocol activity. Challenging students to modify their helicopter to maximize flight time would form a design challenge activity.

**Conclusion**

These eight common strategies go beyond a cookbook form of inquiry. We hope they will inspire teachers to develop innovative classroom activities of their own.

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**On the web**

Stella. 2009. www.software3d.com

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