THE CLASSROOM SANDBOX

A physical model for scientific inquiry

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The National Science Education Standards (NRC 1996) call for the teaching of inquiry, or "the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work" (p. 23). Through this approach, scientific knowledge is constructed by inquiring into the natural world (Minstrell and Van Zee 2000; NRC 2000).

Though all scientific inquiry shares some common features, there is no one method used by all scientists. Kastens and Rivet (2008), for example, describe six modes of inquiry that a geoscientist might use. They include

- the classic laboratory experiment,
- observation of change over time,
- comparison of ancient artifacts with products of active processes,
- observation of variations across space,
- applications of computer models, and
- use of physical models.

Over the last five years, we have taught 8th- through 12th-grade science using one of the physical models that Kastens and Rivet (2008) describe—the sandbox. The sandbox is a piece of equipment used by practicing geoscientists

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to model Earth processes, test hypotheses, and build theory (Del Castello and Cooke 2007).

For scientists, the sandbox serves as an analog for faulting in Earth's crust. Here, the large, slow processes within the crust can be scaled to the size of a table, and time scales are directly observable. This makes it a useful tool for demonstrating the role of inquiry in science.

For this reason, the sandbox is also helpful for learning science *through* inquiry in middle and high school classrooms. This article describes a classroom version of the sandbox and how we use it as a physical model to promote inquiry in Earth science classes.

The sandbox

A classroom sandbox is a 60 × 90 cm (2 × 3 ft.), three-sided box with clear windows built into its two longest sides (Figure 1A). The fourth side is moveable, and has a long screw and crank for pushing or pulling it along the length of the sandbox. Coauthor Michele Cooke developed the classroom sandbox described in this article as part of a National Science Foundation (NSF) project. The box can be built at home or in a school woodshop (see "On the web" at the end of this article and Del Castello and Cooke [2008] for more information).

Depending on how the sandbox is set up, students can explore what happens when crustal blocks are pushed together (contraction) or pulled apart (extension). Watching the action through the side windows, they can observe how and where faults develop and at what angles they form (Figure 1B). Looking down at the surface of the sand, students get a bird's-eye view of what crustal faults look like from above Earth. From their observations, they can predict where new faults are likely to develop and recommend where a hypothetical community might choose to build a new power plant or site a dam. (**Safety note:** As with all laboratory activities, students should wear goggles when using the sandbox and be supervised at all times.)

FIGURE 1

The classroom sandbox.

A. A classroom sandbox before the sand is added.

PHOTO COURTESY OF MARIO DEL CASTELLO

B. A side view of a sandbox after it is filled with sand, showing shifts in the various layers.

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Sandbox as physical model

The classroom sandbox can serve as one of three types of physical models for students (Figure 2, p. 60). The first type of physical model (PM1) is simply a nontextual representation of a phenomenon. This can be a three-dimensional (3-D) model, photograph, drawing, animation, or video. For example, a cutaway drawing of the structure of Earth is a PM1. When students view photos of landforms, such as various faults and mountain types, similar features in the sandbox can help them understand how these landforms were produced in Earth's crust.

The second type of physical model (PM2) can be manipulated so that students get a sense of what happens when the phenomenon is altered. Simple PM2s of Earth deformation might include alternating layers of modeling clay and candy bars. The sandbox can serve as a helpful PM2 in this regard—students can change the depth of the layers of sand, the amount of contraction or extension, or the bottom surface of the box. They can then observe what happens when the model is altered in some way.

Like the PM2, the third type of physical model (PM3) also allows for manipulation. But the PM3 goes a step beyond—it represents the causal relationships among variables in the real world—so it can be used to test hypotheses based on theoretical understandings of the phenomena. As a PM3, the sandbox can be used to model the tectonic processes that produce different landforms. Students can make hypotheses about how the processes cause the landforms, and then use the sandbox to test their ideas.

The sandbox and inquiry

Contraction experiment

The sandbox is a powerful tool; it can help students learn the role of inquiry in science by learning science *through* inquiry. To begin an exploration, students in small groups of three to

FIGURE 2

Types of physical models.

Type of physical model	Properties	Examples
PM1	Representation of the phenomenon	Three-dimensional models, drawings, videos, animations, sandbox
PM2	Representation of the phenomenon that can be manipulated	Interactive animations, modeling clay, sandbox
PM3	Representation of the phenomenon that can be manipulated and used to test hypotheses	Bench-scale laboratory models, stream table, sandbox

five run some trials to better understand how the sandbox works. Then, they are ready to set up an experiment. Students might be interested to see how Earth's crust accommodates the pressure of crustal plates pressing together, a situation called *contraction*. Throughout Earth's history, contraction has produced fault systems that gave rise to large mountain ranges, such as the Rockies and the Himalayas.

To explore contraction, students begin by placing alternating layers of contrasting dark- and light-colored sand in the bottom of the sandbox (Figure 1B, p. 59). A total sand depth of 5–7 cm is recommended. They then smooth the surface of the sand with a trowel or the edge of a ruler and use chalk to mark the starting position of the moveable wall (see on "On the web" and Del Castello and Cooke [2008] for more information on this setup).

When the setup is ready, a student volunteer begins to crank the moveable wall of the sandbox, contracting its layers. After 10 cranks, the student stops, and the class observes what has happened. Students watch for both underground (cross-sectional) and surface (bird's-eye) changes, and then draw both views in their notebooks. They label features such as the position of the moveable wall, the number of cranks, the view (cross-sectional or bird's-eye), and the direction of strain (in this case, contraction).

Next, students add observations to their drawings in their own words. They show the location of any faults that have started in both views. Students interested in the angle of the faults can use a protractor to measure the angle between the horizontal line and the fault. They can also measure the height and width of the mountain wedge.

When all observations have been recorded, a student volunteer turns the crank another 10 times, and students again make notebook drawings, labels, and observation notes. Figure 3 is a sample page from a student's notebook.

When the sandbox is used as a PM2 in this manner, students can investigate any of the following questions:

- Where do new faults develop?
- What is the angle of new faults?
- What happens to the angle of the new faults as more contraction occurs?
- What happens to the height and width of the wedge as the experiment progresses?

In this way, the sandbox is used as a tool for learning science through inquiry.

The sandbox can also be used as a PM3 to really engage students in scientific inquiry. Students can take measurements of locations and angles of faults and estimate the contraction or extension by the number of turns of the crank. Example hypotheses for contraction might include the following:

- The strain within the deforming wedge produces thrust faults.
- New faults will always form at the bottom of the slope (where the weight of overlying sand, which clamps the faults, is less).
- The ratio of wedge height-to-width remains constant throughout the experiment (because the force of the moving wall is matched by the resisting frictional forces along the sandbox's base).
- The angle of the new faults will be the same no matter the speed of contraction or thickness of the sand layer (because fault angle relates to the material's slipperiness).

When the sandbox is used as a PM3 in this manner, students get a sense of the role of inquiry in developing scientific knowledge.

Extension experiment

The sandbox can also be used to inquire into the geologic process of *extension*—or when Earth's plates pull away from one another and stretch the crust. Extension produces large blocks of crust that settle into what is known as a *rift* or *rift valley*. Students can set up an extension experiment by using duct tape to attach a rubber sheet between metal plates that are screwed firmly to the stationary and moveable walls. The rubber sheet provides a broad region of extension, similar to extended regions of crust found in the Basin and Range of Nevada. Students then layer sand in alternating colors up to a depth of 4–5 cm and again mark the starting position of the moveable wall. A volunteer turns the crank five times, and students make observations and drawings.

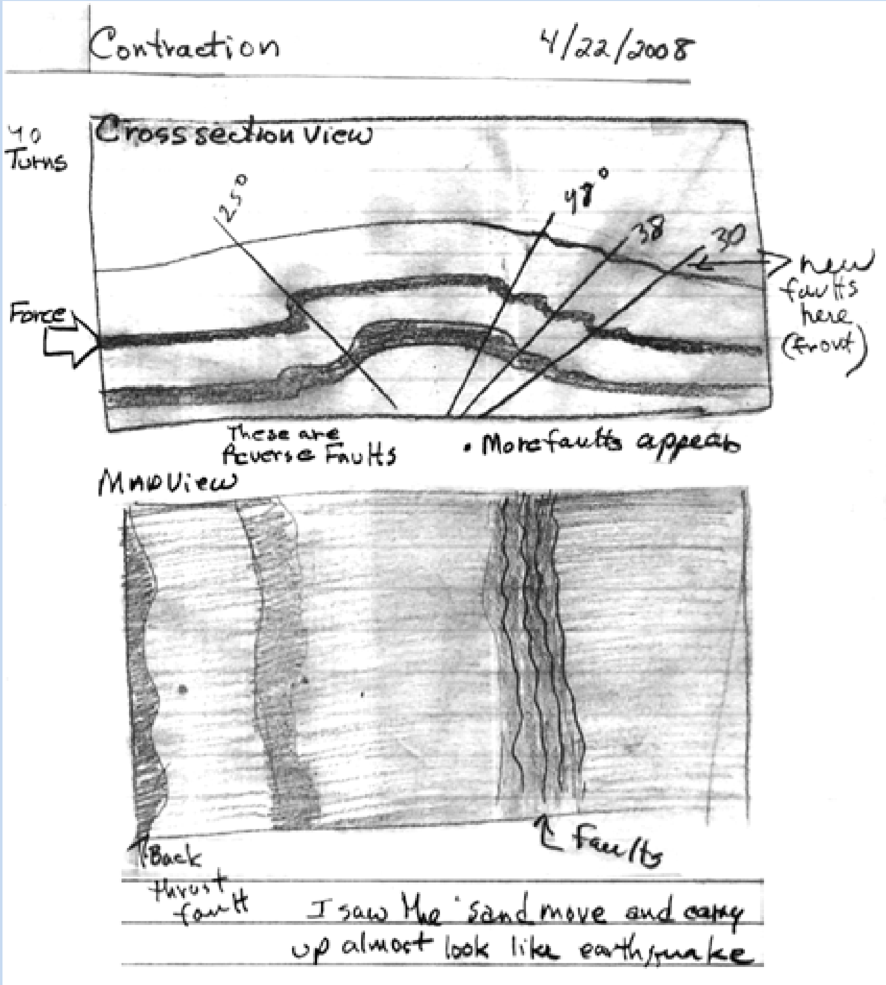
After each increment of five turns, students can investigate the following questions using the sandbox as a PM2:

- What is the angle of the faults?
- Where do the new faults develop?
- How does extension differ from contraction?

FIGURE 3

Sample student drawing.

This page from a student's notebook shows the number of faults developed and the fault angles. The direction of force from the cranking is indicated, along with the location of the newest fault to appear. A note summarizing the student's observations is found at the bottom of the notebook page.



As with investigations into contraction, students can also develop hypotheses about extension processes that they can then test using the sandbox as a PM3. Example hypotheses might include the following:

- The forces within the extended layer produce normal faults (even though the dip direction may vary, the faults are all normal faults).
- The spacing between normal faults depends on the sand layer's thickness (because faults that are spaced closer than their length will interact and one will dominate).
- The angle of faulting within the extension experiment is consistent with the angle within the contraction experiment (the different directions of the relative forces produce different angles).

Assessment

The type of assessment used for sandbox activities depends on how, why, and for whom the sandbox is used. Preassessment can involve asking students—prior to an activity—to predict what will happen when the walls are cranked together (or pulled apart). Students can also verbalize their observations and share their drawings as a formative assessment of their understanding. This helps identify misconceptions and clarify how students understand what they are seeing. Lab reports, notebooks, and regular classroom testing can provide summative assessment opportunities.

Teachers who use sandboxes in their classrooms find that they are able to address a number of common misconceptions. For example, many students think faults are perfectly planar features, but when working with sandboxes, they realize that faults actually vary in shape. Another common misconception is that geologists only study rocks, but after working with sandboxes, students begin to see the work of geologists as understanding processes, developing theories, and quantitatively investigating Earth through modeling. Students might also believe that mountains form because Earth's surface is somehow pushed up from underneath. In sandbox modeling, they can see the accordion-type action of repeated faults in an area and are able to infer the direction of the forces in addition to understanding the movement of the sandbox boundaries.

Conclusion

One student, a junior in coauthor Mary Ellsworth's class, wrote the following in her notebook after using the sandbox in her classroom: "I understand better why there are mountains and valleys and how they developed over millions of years. It gives me a better sense of how old the Earth actually is, which is quite amazing."

As demonstrated by this quote, the classroom sandbox can provide students with a depth of understanding about the Earth. The observations and measurements of fault formation help students better appreciate the geoscientist's task of sorting out the principles that determine the formation of faults, mountains, rift valleys, and other tectonic features. Using the sandbox for authentic inquiry in the classroom, students are able to gain a deeper understanding of geological principles and the ways in which geologists actually *do* science. ■

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On the web

More information on classroom sandboxes: *www.geo.umass.edu/sandbox*

Resources

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