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"I've seen that one before" secondary teachers often mutter when we demonstrate this geologic timeline activity during NSTA workshops or short courses. The audience, however, is soon engaged when they realize that the innovation, in this case, is not our activity but how it is used in a constructivist classroom. This project provides evidence that time-honored activities still have a place in today's science classes. Often the way an activity is presented can make the difference between a simple laboratory activity and an involved, learning experience.

When modeling geologic time in the past, our students were given the classic list of events with times they calculated and scaled on five meters of adding machine tape. They always managed to do the conversions necessary to determine that one millimeter equals one billion years. We felt, however, that students were just going through the motions. With nothing vested in the activity, there was often little thrill or discovery. We knew there had to be a better way to make this classic model for geologic time minds-on, and we wondered how we could develop an activity that allowed students to manipulate the data, explore their understanding, and confront misconceptions. The answer lay simply in resurrecting the old clothesline model with a constructivist slant.

Engaging the students: Ordering events

To prepare for the activity, we copy the 28 events in Figure 1 onto a card stock and cut a separate card for each event. Laminating the cards increases their longevity and reduces future preparation. We divide students into groups of four and give each student a card. Depending on the class size, cards can be left out or added, or additional cards may be given to some groups. We ask students to discuss the events, and based on their prior knowledge, decide as a group which came first and last. Energetic scientific debate typically ensues at this time as students attempt to determine the correct order.

At this point, vocabulary questions may arise. For example, some cards refer to the various tectonic events that formed the Appalachian Mountains—students are surprised to discover that an orogeny is a mountain building incident. This gives students a reason to learn the vocabulary and immediately use it in context; therefore, they do not easily forget the words and their definitions.

Exploring: Time on a line

We used to string the traditional 4.6 m clothesline somewhere in the classroom to give students enough space to construct a model of geologic time. This proved cumbersome and was difficult to display during the unit. Using a timeline composed of hook and loop fasteners is a more manageable approach. The model can be left permanently on the wall and used alternatively throughout the semester for hanging posters or student work. Rolls of hook-and-loop fasteners, approximately 5 m long, can be purchased in office supply stores. A small hook is adhered to the back of each card, and students are instructed to place their events on the line in the order they occurred, relative to other groups' events. The spacing is irrelevant at this point since students have not yet associated this exercise with a timeline. Each group is given a few minutes to discuss their card placement before approaching the line, and groups are permitted to shift cards to make room for new ones.

As the groups place their cards, we ask questions about the terms on the timeline. The students that have cards with specialized vocabulary define their events to the

Reconstructing the

class. Archaeopteryx (first bird), Lucy (ancestral human), Ediacaran (primitive yet multicellular life forms in Precambrian), and orogeny are examples of vocabulary that should be clarified. A discussion often results involving what students in other groups know about each of the events. Adjustments to the timeline are made as new information surfaces. At least one student usually knows that birds evolved after the first dinosaurs, and we use this deduction to focus on students' prior knowledge. For instance, students generally recognize that the simpler organisms evolved first and readily associate the Mesozoic era and Jurassic period with dinosaurs. Also, many recognize humankind's presence as a fairly recent development in the scheme of things. Oftentimes, however, exploring their prior knowledge reveals misconceptions, such as the belief that dinosaurs predated mammals or that life is evolving into more complex organisms.

Elaboration: Constructing scales

Once the discussion is exhausted and students have made last-minute changes in the event positions, it is time to verify the order. Figure 1 (page 34) is replicated as an overhead for this stage of the activity. Using an overhead projector, the students are only shown the left column of the table (the "years ago" column remains hidden). By revealing the correct sequence, we open the door for further discussion about errors, rationales, and misconceptions. Some students are surprised to find that mammals actually coexisted with dinosaurs. Previously certain that all dinosaur species were contemporaries, they are amazed to discover that the Tyrannosaurus Rex did not regularly fight with the Stegosaurus. A more subtle revelation is the relatively late evolution of grass compared to other events. The discussion of grass as a highly specialized, flowering plant clarifies any confusion. Grass adapted to be cropped from its apex to withstand constant "mowing" by grazers. This discussion also presents the opportunity to address the classic misconception that early humans coexisted with dinosaurs. After establishing the proper order of events and their alternate conceptions, we ask "How can we make our model more representative of geologic time?" The students determine that it needs to be "like a timeline in history."

At this point, we integrate mathematics and scaling into the activity by asking: "You have 4.6 m of hook-and-loop fasteners to represent geologic time. Using the metric system, what unit could you use to represent a billion years?" Students identify 1 m as the appropriate unit to represent one billion years. To make sure everyone understands this concept, we ask students to develop a scale that can be used to arrange event cards. Working collaboratively in their groups they determine that 1 cm equals 10 million years, and 1 mm equals one million years.

Attention now turns back to the hook-and-loop fasteners line, and Figure 1 is distributed as a handout.

Expansion: Students construct a time scale

Using their new scale, students convert the events on their handout (Figure 1) into a timeline with calculated distance. We move between groups and observe peer instruction as students explain the conversion process to one another. The groups work cooperatively to calculate the distances between each event.

Once the event times have been converted, they are ready to be moved onto the timeline. Using metersticks and metric rulers, groups return to the line and replace their original events. The product is a scaled model of geologic time that can be left up during the semester. The traditional observations from the adding machine tape activity are addressed as students comment on the lack of events present on the early portions of the timeline. Many students become frustrated trying to place events of recent time using the correct spacing since these are usually only millimeters apart.

Geologic Timeline

Adding a constructivist slant to a classic activity

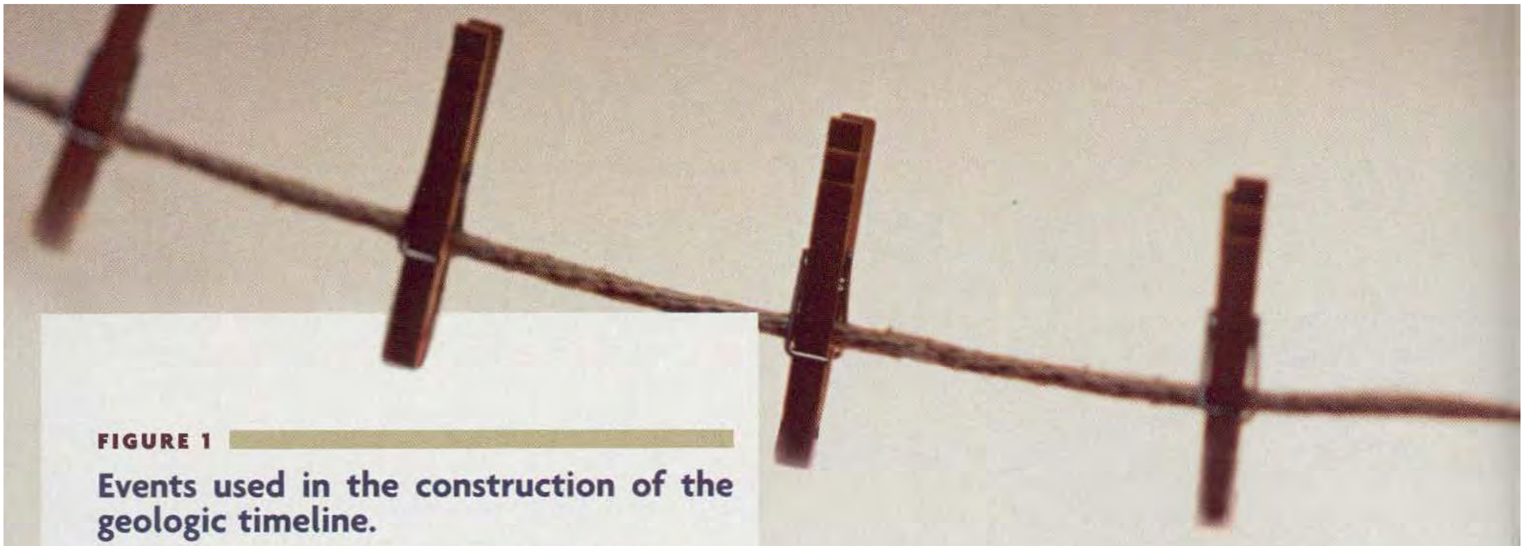

FIGURE 1

Events used in the construction of the geologic timeline.

Event	Years Ago	Scale Distance
"Lucy"	4 mya	
Camel	35 mya	
Grass	55 mya	
Cenozoic era (begins)	65 mya	
Tyrannosaurus	65 mya	
Ants	100 mya	
First flowering plants	125 mya	
Archaeopteryx	140 mya	
Stegosaurus	160 mya	
First mammal	240 mya	
Mesozoic era (begins)	250 mya	
Pangaea forms	260 mya	
Earthworms	300 mya	
Allegheny orogeny (begins)	320 mya	
Cockroaches	330 mya	
Ferns	370 mya	
Sharks	400 mya	
Acadian orogeny (begins)	410 mya	
Spiders	450 mya	
Taconic orogeny (begins)	460 mya	
First vertebrate	515 mya	
Trilobites	520 mya	
Jellyfish	545 mya	
Paleozoic era (begins)	545 mya	
Ediacaran	600 mya	
Green algae	1 bya	
Bacteria	3 bya	
Precambrian era (begins)	4.6 bya	

Note: (mya = million years ago, bya = billion years ago) These dates are approximations and will vary depending on the source consulted. The event list was modified from Scotchmoor (1996). Dates used in this figure were obtained from Pan Terra, Inc. (2000).

Evaluation: Creating a new time scale

To evaluate students, we assign groups a period or epoch to investigate. We encourage each group to identify at least 10 significant events in their period. They demonstrate their understanding of the material by selecting a scale for these events, using ratios to calculate distances, constructing their timelines, and presenting their results to the class as poster models of geologic time (Figure 2). A rubric for assessment can be developed based on proper scaling, geologic historical accuracy, clarity, and group cooperation.

The products of this group activity can be placed around the room as reference for future class discussions. The student-created timelines can be used to illustrate points during a lecture, generate more questions for discussion, or be employed for individual investigations. The students have come full circle; their questions are used to guide future instruction. This is an example of student-directed learning.

This activity can be tailored to the needs of any classroom. For example, if hook-and-loop fasteners are not feasible, teachers can use adhesive magnetic tape on the event cards, which is compatible with many modern blackboards. The traditional clothesline can be hung between a VCR cart and an overhead projector arm. In addition, the activity event can be modified to more closely relate to specific geographic areas. In the Eastern states we tend to focus on the Appalachians. Western states might focus on the Laramide and Sevier orogenies. We highly recommend that any significant geologic event in the area, such as an earthquake, be added to the timeline. This enhancement, rather than sticking solely to a generic textbook list, makes the project more relevant to the local area.

Also, some teachers in past workshops have expressed an interest in modifying the activity by using multiple timelines. We tried this at the recent NSTA meeting in Columbus with great success. Four hook-and-loop fastener lines were placed in the room (one

Activity Outline

1. Give each student an event card and divide students into groups (distribute any extra cards to assembled groups).
2. Have groups arrange the events from oldest to youngest.
3. The hook-and-loop fastener line is identified as a timeline of Earth's history. Student groups place their events in order of occurrence on the line.
4. Discussion with the class involves and expands on prior knowledge that students use for placement of events and clarification of unfamiliar vocabulary.
5. The correct order of events is provided on an overhead and students discuss misconceptions and revelations.
6. Because the hook-and-loop fastener line is 4.6 m long, a scale for the 4.6 billion year history of Earth is then devised by the students and verified by the instructor.
7. Students are provided with a handout of Figure 1. The groups convert the event times to distances for timeline placement.
8. Student groups use meter sticks and metric rulers to place their events to scale on the hook-and-loop fastener line.
9. Discussion of event development, spacing, and relative length of eras is facilitated by the instructor.
10. Student groups are assigned a period or epoch to research. Events are identified, a scale is selected, a poster of timeline is created, and events are added to the timeline. Groups present their timelines to the class.

on each wall), and the class was divided into four groups. Fewer students work directly with more geological events, which increases student engagement. The only consideration is added time investment. The exploration phase lasted longer because more groups had to resolve conflicts over event placement. If time is not an issue, then we advocate the use of several timelines.

In true constructivist fashion, students become engaged in a topic, demonstrate their prior knowledge, assimilate new concepts into their existing frameworks, apply their knowledge, and are evaluated using performance assessment. Students work in collaborative groups that are engaged in peer teaching and evaluation. Robert Yager, a noted educator and former NSTA president, wrote that teachers could move toward constructivist approaches with very little shift in their current practices. All that is truly necessary, he said, is "reorganization with a new emphasis" (2000, 45). Many teachers have valuable activities that only need to be complemented with more focus on the student. With a little tweaking, a time-honored activity can become "constructive."

FIGURE 2

Cambrian period timeline

An example of authentic assessment that could be used for this lesson is a student generated timeline. The following is a student sample of a timeline for the Cambrian period timeline (scale: 1 cm = 2 million years).

495 mya	Mass extinction/in WV beginning of Ordovician similar
	Trilobites speciation reaching peak (more than 90 kinds)
	Mass extinction
	Conodonts evolve
	Mass extinction
	Sea conditions continue in WV
	Carbonate muds accumulating in WV
	Tommotian life present
	Life in the Burgess Shale develops
545 mya	West Virginia is underwater

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