Geodesic Earth

Models help students understand the size and scale of the Earth

MAKING SCALE MODELS IS AN EXCELLENT way to integrate science and mathematics. To provide a physical framework for science education, we use geodesic spheres as models to convey not only size and scale but also the interior of objects such as the Earth. Students can use models to learn about Earth's structure, composition, size, and geography while also learning mathematical and verbal skills and studying science history.

During discussions in our eighth grade integrated science class, we found that students have many misconceptions about the Earth. To teach them about the planet's three-dimensional nature, we designed an activity that incorporates mathematics skills into the building of an Earth model. The activity required students to work cooperatively to research and create the model. The project takes approximately six weeks to complete.

BUILDING ON KNOWLEDGE

To begin, we asked students to write an essay titled "What I know about the Earth." Students were encouraged to supplement their essays with diagrams, charts, or other forms of graphic information. When completed, the essays were collected by the instructor, read, and filed for comparison with post-project essays.

Next, the class compiled a list of 36 questions about Earth. Students were then assigned to six different groups, each of which was given six questions to research as a team. Their charge was to find reasonable answers from the classroom resources available and to design and prepare mini-presentations including artwork, charts, diagrams, and activities for the class at the completion of the project. Each team kept a running log of which students researched the questions, did artwork, and performed other duties. This work was done concurrently with the building of the scale model of the Earth.

After completing the project, each student wrote an essay titled "What I now know about the Earth." A comparison of the pre- and post-project essays was made using the following scale:

- Student increased knowledge base by less than 25 percent—no points.
- Student increased knowledge base by 25-50 percent—1 point.
- Student increased knowledge base by 50-75 percent—2 points.
- Student increased knowledge base by 75-100 percent—3 points.
- Student increased knowledge base by more than 100 percent—4 points.

A careful reading of both pre- and post-project essays was necessary to compare the number of concepts represented accurately in each. Most students increased their Earth knowledge base by more than 75 percent. The percent of student increase in knowledge was determined by counting the number of correct facts presented in their pre-test essays and comparing the total to the number of correct facts in the post-test essays. Students who already had considerable pre-knowledge were not penalized because their papers were compared to the list of objectives for the unit. If they demonstrated high levels of mastery, they were given a 4. These points were later added to points gained in other sections, such as the rubric in Figure 2, for a possible total of 24 points.

GEOMETRY AND CONSTRUCTION

The icosahedron used as the framework structure in this project has 20 equilateral triangular faces that connect to form a sphere-like shape. As a class, we discussed the triangle as the strongest building structure and the basis for many natural and architectural structures. The triangular faces of an icosahedron are used in the Dymaxion Airocean map of the world by Buckminster Fuller (1938) to depict the landmasses and oceans of the world with very little distortion. As part of their research assignment, students were encouraged to use the Internet to research the fascinating details of Buckminster Fuller's life and work.

The wooden frame for the geodesic sphere struc-

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ture was constructed in one 45-minute class period. Students were not given detailed instructions on constructing the sphere itself, only general guidelines that included safety instructions. (See Figure 1 for detailed instructions for teachers.) The construction was done on the floor in a 2- × 2-meter cleared area of the classroom. (If space is limited, the model can be scaled down.) Students were told to use all of the available materials and to attach the 20 triangles to form the icosahedron.

Each day, each group assigned one member to work on construction while the other members researched and developed the group's presentation. When the structure was completed, it was covered with black garden plastic secured with duct tape. Oceania was left open to allow viewing of the interior of the "Earth."

To accurately depict the landmasses and oceans of the world, we copied the Dymaxion Airocean map as a transparency and used an overhead projection of it for students to trace the various triangles of the geodesic sphere onto paper. Two students numbered the Dymaxion Airocean map's triangles to facilitate placement of each triangle on the large structure. After being traced, the landmasses were colored, cut out, and attached with duct tape to the appropriate triangles of the icosahedron on the black garden plastic. This provided a large reference model of the Earth for students to use as they made their presentations.

In addition to geometry, other aspects of mathematics were encompassed by this project. When the model was completed, students measured its diameter in metric

FIGURE 1.

Geodesic Earth model instructions.

The materials needed for this project are:

- One meterstick per group
- Crayons or markers
- Two sheets of poster board per group
- One pair of scissors per group
- Several rolls of string
- Overhead transparency of Dymaxion Airocean map
- One roll of cellophane tape per group
- One calculator per group
- One roll of butcher paper
- Several rolls of duct tape
- Overhead projector
- Various resources for student research
- Thirty wooden struts of the same length
- Twelve starplates (purchased through an agriculture supply company)
- Sixty nuts, bolts, and 5/16-inch washers
- One 5/16-inch wrench per group
- One large roll black garden plastic
- Wood, cardboard, or poster board for the inner and outer cores
- Clamp light
- Red bulb
- Extension cord
- Rope to suspend inner and outer cores

The wooden model is first constructed and then covered with black plastic and the map. The struts may range from 0.6 to 2 meters in length (size is largely dependent on classroom space). Prior to construction, the wood must be drilled 4 centimeters from the ends through the widest part of the strut and the 5/16-inch carriage bolts placed through the holes. The holes should be drilled in the wood so that a connection with the starplates is accomplished, and the struts remain the same length. (Measure from hole to hole, not from end to end of the wooden strut). Make sure the bolts come out the drilled side so that the connections remain equal distances apart.

Students must wear full-wrap, splash-proof goggles. They begin the construction of the geodesic sphere with one triangle with a starplate at each of the three vertices. Each of the wooden struts should be attached to the starplate connectors with bolts, nuts, and washers, with students finger-tightening the nuts before using wrenches. The goal is to use 30 wooden struts, 12 starplates, 60 bolts, 60 nuts, and 60 washers to complete an icosahedron. Depending on the size of the wooden struts chosen, step stools may be necessary. Students must understand that each side is a triangle; no other shapes will work. As the first several triangles are finger-tightened and then tightened with a wrench, students will see the creation taking shape.

In a very short time, the icosahedron will be finished. Make sure that each of the nuts is tightened with a wrench. Cover the structure in black garden plastic secured with duct tape or with cloth and Velcro. When the structure is complete, students can use an enlarged overhead projection of a Dymaxion Airocean map (available electronically from the Buckminster Fuller Institute at *www.bfi.org*) to make landmass models that may be colored and added to the exterior of the sphere. Our model used simple drawings of the landmasses, but three-dimensional, topographic mapping would also be appropriate.

Leave part of the structure open so the interior may be viewed with the outer core, inner core, and the mantle labeled and constructed to scale. A ball or other spherical object of the proper size may represent the inner core, and the outer core may be represented by a cardboard or wooden construction made to scale. We used two wooden circles of the proper diameter to represent the inner core and connected them together with one circle placed vertically and the other horizontally. The light was placed on the horizontal circle of wood to illuminate the interior.

During construction of the large geodesic sphere, rotating construction crews allow teachers to manage a large class of students. Not all students in a class of 30 can actively build at the same time!

units; the sphere measured approximately 2 meters in diameter. Students used classroom reference materials to determine the actual diameter of the Earth, 12 756 kilometers, and the actual diameter of the inner core, 2400 kilometers (Shipman and Wilson, 1987). To determine the correct diameter of the scale model's inner core, students used the following: The diameter of the model/12 756 kilometers is equal to the diameter of the scale model's inner core/2400 kilometers. Therefore, because the diameter of our model was 2 meters, then the expression would be .002 kilometers/12 756 kilometers is equal to x/2400 kilometers, and x would equal 0.376 meter.

Students built a scale model of the inner core and placed a red light in it to represent its high temperature. The model's outer core and mantle thicknesses were derived similarly to how the model's inner core diameter was found, and the actual thicknesses were found in resource materials. The outer core and mantle were then constructed to scale and placed within the model Earth. The mantle layer was constructed to show subduction zones and hot spots.

Finally, each group presented the answers to their research questions. These presentations were scored according to the rubric shown in Figure 2.

GOALS AND OBJECTIVES

The *National Science Education Standards* emphasizes learning the structure of the Earth system and technological design as objectives for students in grades 5–8 (National Research Council, 1996). Likewise, the instructional goals and objectives for West Virginia schools were followed throughout this project and include the major themes of systems, changes, and models. Depending on the nature of the questions posed by students, forces and energy, change and constancy, and life science concepts may be addressed as well. The history of science, through discussions about Platonic solids and Buckminster Fuller's inventions, is also integral to this series of activities.

In a truly active fashion, students explored Earth science concepts as they participated in a student-driven project that gave them a sense of ownership of their learning. The essence of scale modeling was captured by one student's comment at the project's completion: "Look, we shrunk the Earth!" ✧

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REFERENCES

Fuller, B. 1975. *Synergetics—Explorations in the Geometry of Thinking*. New York: Macmillan Publishing.

National Research Council. 1996. *National Science Education Standards*. Washington, D.C.: National Academy of Sciences.

Shipman, J. T., and J. D. Wilson. 1987. *An Introduction to Physical Science*. Lexington, Mass.: D. C. Heath and Company.

West Virginia Department of Education. 1996. *Instructional Goals and Objectives for West Virginia Schools*. Charleston, W.V.: West Virginia Department of Education.

FIGURE 2.

Rubric for group presentations.

Criteria	1	2	3	4
Accuracy	inaccurate or misleading information throughout	some inaccuracies in presentation	few inaccuracies	accurate in most areas
Creativity	mere reading of information; no visuals in presentation	some spontaneity in presentation; includes some visual material	novel approaches; visuals used to describe and/or explain	novel and unique approach; visuals neatly completed
Clarity	mumbled; disorganized information	some disorganization; poor presentation	explanations clear; most of presentation is engaging and interesting	clear, easy-to-understand explanations; engaging and interesting
Shared responsibility	group worked poorly together; one member of the group dominated	team members seldom worked well together; work was not equally distributed	team members worked well together most of the time; most work was equally distributed	team members worked well together; all members contributed to presentation