IBI* SERIES WINNER

Engaging Students in Earthquakes via Real-Time Data and Decisions

Seismicity and Relative Risk, the IBI Prize–winning module, utilizes freely available earthquake data to help students apply their knowledge to risk-related decision-making.

Anne E. Egger

The topic of earthquakes appears in virtually all introductory undergraduate geoscience courses. Most students entering these courses already have some knowledge of earthquakes and why they occur, but that knowledge often derives from the most recent event in the news and can therefore be biased toward the most destructive earthquakes (*1*). In addition, students arrive at college with misconceptions (*2*, *3*), perhaps picked up from erroneous or poorly presented media coverage. These misconceptions can go unchecked or even be reinforced by introductory textbooks, most of which contain errors and oversimplifications about earthquake processes (*3*, *4*).

But we need not rely on the news media and textbooks in teaching. Earthquakes happen every day, and an exciting thing about earthquake science is near-instantaneous access to data collected by a global network of seismometers. The U.S. Geological Survey's (USGS) Earthquake Hazards Program hosts a Web site that serves data from that network in real time (http://earthquake.usgs.gov). Anyone can access and explore the data, which are available in both raw and interpreted form with supporting information. During 9 years of teaching introductory geoscience courses, I developed and refined an inquiry-based module called "Seismicity and Relative Risk" to take advantage of this reliable resource to engage students in learning more about earthquakes.

The refining part was instructive. Initially, I asked students to explore a static map of earthquakes (such as shown in the map) and then to write an essay that related earthquakes to plate boundaries. The results were disappointing. Students did not know how to describe patterns in the distribution of earthquakes or even seem to understand what "relate earthquakes to plate boundaries" meant. I realized that I was not giving them all of the tools they needed. Recent research shows that students often do not recognize that these static maps consist of data collected and analyzed by scientists; instead, they see them simply as "pictures" (*5*). In addition, about half of the students in introductory geoscience courses are not prepared for the level of abstract thinking that this assignment required (*6*). There are many learning benefits to be gained from incorporating data into classroom teaching (*7*); I needed my students to get their hands on these data so that they would become real for them.

Over the next few years, I tried different ways of incorporating data from the USGS site in class. In one version, pairs of students examined different regions and presented what they found in a few slides. This helped with describing patterns, but was tedious and repetitive for both me and the students, and it never got them beyond their descriptions. In the next version, students answered a series of questions that guided them through the USGS site. This was better, but students worked at very different paces; it was hard to

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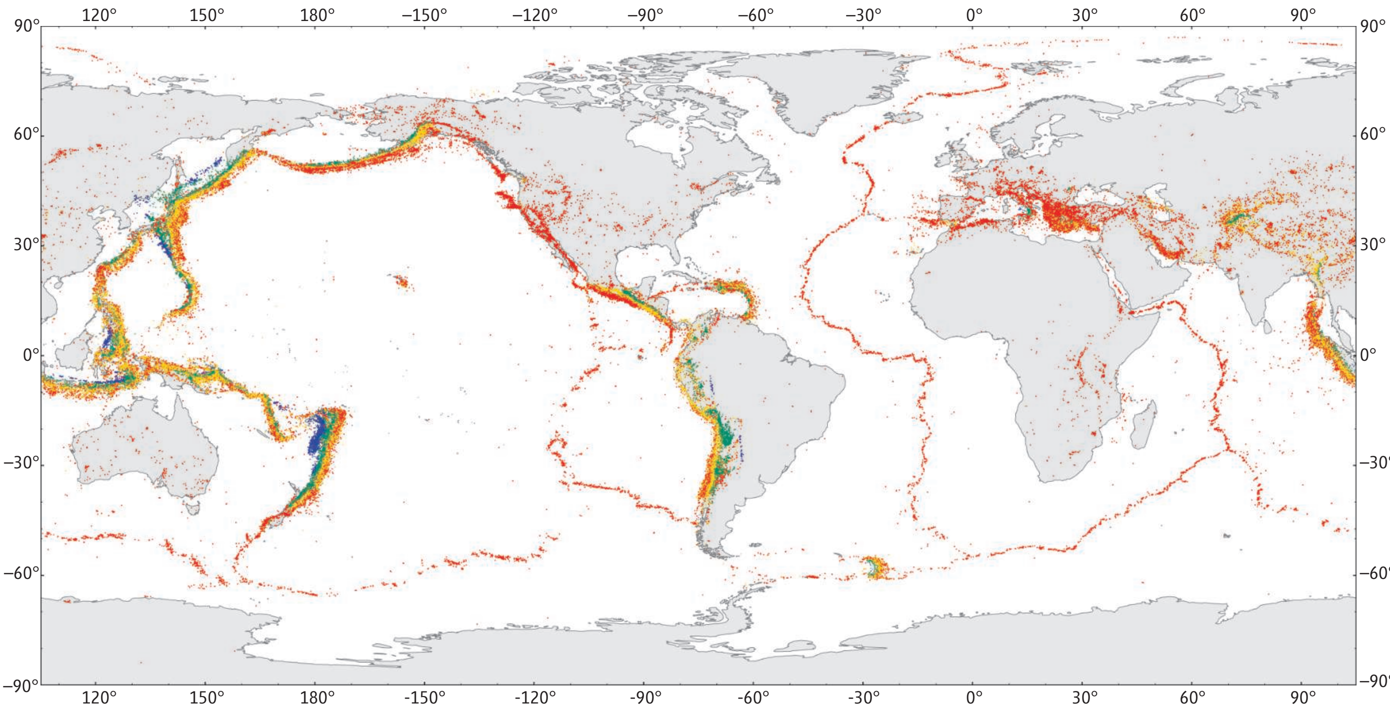

Earthquakes displayed. Global distribution of earthquakes greater than magnitude 3 from 2002 to 2011. Color represents the depth of the earthquake origin: red, 0–33 km; yellow, 33–100 km; green, 100–400 km; blue, >400 km.

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finish class on time, and the questions were a challenge to grade fairly and boring to read.

Finally, I realized that having students navigate the USGS site was not my goal. Instead, I wanted them to be able to use and apply the information they found. The module's current three-part form leads from learning how to interpret the site to an in-depth exploration in which students have personal interest (*8*).

In the first part, students work in pairs on computers in class in highly structured inquiry (see the photo). After recalling that most earthquakes have occurred along the boundaries between the Earth's tectonic plates (see the map), students describe the distribution of recent seismicity around the world. They note that most, but not all, earthquakes fall into that familiar pattern. The class (35 to 80 students) is lively: Students exclaim when they see how many earthquakes have happened nearby, or how many occur in unexpected areas, and they ask a lot of questions. In class discussion, they volunteer interpretations for these "unexpected" earthquakes, and I provide feedback and a brief lecture about the causes (*8*).

Then the students drill deeper into one of those dots on the map. Each pair chooses a recent earthquake to look at in detail and to describe exactly which data were collected—and how. In discussion, they define the difference between earthquake magnitude (a measure of the energy released in the earthquake) and intensity (the extent to which it is felt at a particular place, which depends on several factors such as the earthquake magnitude, distance to the earthquake, and surface geology). They analyze the individual earthquake in the context of its location and tectonic setting. The first part of the exercise fosters the transition from an individual earthquake to the more abstract idea of how earthquakes relate to plate tectonics, providing them with the skills and understanding for simple analysis and interpretation.

Exploring the USGS earthquake site.

They use these new skills in the second part of the module, which demands more abstract and open-ended inquiry. I ask students to write a brief paper summarizing the seismic activity of three different cities where they might move after graduating, in which they compare the risks associated with living in each location and choose which city they will live in (*8*). For a complete answer, students must determine which data about earthquakes are most relevant to a discussion of risk, formulate the appropriate questions to ask about those data, and assess the data to make a decision. There is no right answer, but students must justify their decisions.

This requires students to ask fundamental questions that may affect their lives. Is it riskier to live in a place with large, very deep earthquakes, or smaller-magnitude but shallower earthquakes? What about the tsunami danger? How prepared is the municipality to deal with a disaster? By personalizing the topic of earthquakes, I hope to provide situational interest in the topic, which has been shown effective in promoting learning (*9*). Although students sometimes express frustration that I do not tell them exactly what data they need, all of the information is easily accessible on the Web, and the exercise of using the USGS Web site provides them with the skills to search and access it.

A major advantage to this writing assignment is that each paper is unique, making them far more fun and interesting to grade than earlier versions of the assignment. I use a rubric for grading that emphasizes content, analysis, and coherence of the argument (*8*).

The final part of the module takes place in class after I have read their papers. I compile their decisions and show them the results. One location is never chosen unanimously, and the choices are often quite evenly spread, which prompts a discussion about which factors students weighed differently and why. Students gain a new appreciation for how different people interpret and weigh risk, as well as the inherently incomplete nature of the geologic record. I use this as an opportunity to lecture briefly on the complex role that science plays in policy and decision-making and about ongoing research on earthquakes and how students can get involved if they are interested.

One of my goals for this module is to empower students to use data to satisfy their own scientific curiosity, so they may be engaged in the scientific process beyond this introductory course. Many students have contacted me after the end of course to tell me that they looked up an earthquake that they felt, or pointed someone else to the Web site to see just how many earthquakes occur in the Bay Area every day; sometimes they have pointed out errors that they have heard in the news reports about earthquakes. By allowing students to work with real data in real time, they develop a personal connection and positive affect that motivates their future learning.

About the author

Anne E. Egger is an assistant professor at Central Washington University, jointly appointed in Geological Sciences and Science Education. The development and refining of this module took place while she was teaching at Stanford University, where she was a lecturer and the undergraduate program coordinator in the School of Earth Sciences. At Stanford, she extensively revised the introductory geoscience course to include more hands-on and inquiry-based activities such as this one. Egger's research involves combining the tools and techniques of geology and geophysics to better understand the geologic history of tectonically active regions. She is the codirector of Visionlearning (www.visionlearning.com), where she has authored modules for students in introductory science courses and coauthored a book titled *The Process of Science.*

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Supplementary Materials
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