The many unanswered questions about natural hazards and the difficulty to predict them make them a most suitable topic for inquiry-based classroom activities. The abundant information about and frequent occurrence of natural disasters supports even further the learning of key earth science concepts in a way that it is intellectually challenging and personally meaningful.

To promote this approach to education, the authors offered a week-long “Mapping Natural Disasters” workshop to 30 K-12 teachers during the summer of 2001. The workshop modeled the effective integration of hands-on activities, internet-based data, and use of geographic information system (GIS) software, a powerful analytical tool that displays the spatial distribution of data. Teachers deepened their understanding of current earth science concepts through models and simulations, and then applied this understanding as they analyzed data downloaded from the internet and mapped with the GIS software. In addition, the workshop modeled techniques for promoting student inquiry and reflective professional practice among teachers that may be applied to other curriculum units.

Keywords: GIS, mapping, inquiry, natural hazards, middle-school, earth science, disaster.

INTRODUCTION

Finding science activities that encourage students to explore, analyze, and learn the science behind the forces of nature is a never-ending challenge. There is, however, good news for science teachers who find themselves caught in this struggle. Recent articles point to natural disasters as a topic superbly fitted for such a task. College courses using natural disasters as a main topic, which are offered under names such as earthquakes and volcanoes, geohazards, or environmental geology, are a popular choice among non-science majors who need to complete their general education science requirements. These courses have not only increased student enrollment, but have enabled students to attain a level of proficiency in science that is comparable to that obtained by taking traditional science courses (Nielsen, 2001; Zebrowski, 2001). Based on the success of these models, the authors developed a program for elementary and secondary teachers focusing on natural disasters, with the expectation that such a course would achieve similar benefits for the K-12 students served by these teachers.

A more correct term to describe natural disaster is “natural hazard” (nature creates a hazard, which only becomes a disaster when the population has not properly prepared for). Our discussion centers on natural disasters, as their human impact is more likely to capture the students’ attention and thereby provide the springboard to student interest in (and understanding of) earth science.

Taken at a very general level, natural disasters form a collection of periodic but unpredictable events. Records of these events range from ancient disasters (e.g., the eruption of Santorin, which many believe to be the cause of the destruction of legendary Atlantis) to recent events (e.g., the 1995 Kobe, Japan earthquake), to those that are currently occurring. These disasters affect the population in a variety of ways. Efforts to understand the causes and impact of a given disaster lead naturally to a study of the underlying forces. Framed in this context, students have a strong motivating purpose in learning relevant earth science concepts as they seek to understand and explain the phenomena that have grabbed their attention.

Beyond the science that explains how a hazardous event came to be, the actual damage inflicted by a given disaster depends on a large number of other mappable factors as well, including population density, building codes, and the presence of roads and underground pipelines. Other effects may not be as obvious but still may be significant, such as the impact on a region’s tourism or the increase in the price of durable goods such as lumber. All these complex associations with real life situations make student investigations more authentic (thereby increasing motivation), and are helpful in the integration of other subjects such as health, social sciences, geography, and history (Stewart et al., 2001; Royce, 2001; Zebrowski, 2001).

An additional benefit is the ability afforded by real-world phenomena to incorporate inquiry-based learning into the classroom. While many basic questions about causal forces have been answered due to the rapid advancement of science in the last few decades, there remain many unanswered questions. This fact, coupled with the continuing difficulty of accurately predicting the precise occurrence of disasters, provides an excellent resource for inquiry-based exercises that help elementary and secondary students understand science as an evolving discipline (Royce, 2001) as well as at the...
college level (Zebrowski, 2001). In fact, the entire issue of predicting natural disasters offers a very productive path for student inquiry as they investigate the evolution of monitoring and warning equipment.

**BUILDING ON INTEREST TO DEVELOP UNDERSTANDING**

The spectacular outcomes of natural hazards such as earthquakes and hurricanes attract the interest of adults and children alike. Elementary teachers in rural Missouri agree that bringing up the topic of tornadoes stimulates class participation, as every child has a personal story to tell (B. Cantrell, personal communication). Just as Missouri lies within the Tornado Alley of the southern Midwest or California near active faults, most places on Earth offer examples of one or more natural hazards. Using the powerful forces of nature to grasp the students’ attention can be a first step toward deepening into science concepts. From there, hands-on activities can build student understanding of the key earth science theories underlying the disaster and to challenge common misconceptions (DeLaughter et al., 1998).

With students’ interest piqued and their understanding of the necessary science concepts enhanced by hands-on activities and relevant background readings, they are better equipped to interpret and analyze the volumes of data available to them through the internet. Skillful guidance on the part of teachers supports effective location and use of online databases such as those used to record storm paths, seismic activity, and flood stages (Coulter, 2001). Simply turning students loose to explore the internet is inadequate; instead, teachers need to model for their students how to “read” the data and to interpret it in light of their growing understanding of earth science concepts. Effective data analysis skills are required to judge which data to accept as accurate, how to handle unusual data, and how to raise new questions based on the data (Feldman et al., 2000). Developing these skills is well worth the effort, however, as productive use of these databases serves to further develop student understanding and interest, as they now can feel that they are engaged in meaningful inquiry and not simply learning inert facts from a textbook (Felder and Brent, 1999).

An exceptional tool for maintaining and even increasing this high level of interest in earth science is geographic information system (GIS) software (Curtis et al., 1999; Keiper, 1999; and Bednarz, 2000). GIS technology—essentially mapping software that produces a spatial representation of the data—works by processing “themes” that overlay on each other. Each theme depicts one parameter; for example, to a world map, a student can add one theme showing countries’ political boundaries, one showing the tectonic plate boundaries, one showing earthquake epicenters, and one showing major population centers (cities). The final product will show all five themes in one map, which can serve as the basis for a number of investigative queries. For example, students can use the map to investigate which regions of the world are most prone to seismic activity, and among those regions, which are the most heavily populated. Since each layer is built from an individual data set, students can manipulate the software to display only the most relevant data (e.g., earthquakes above a certain magnitude, or cities above a certain population). As they do this, students develop critically important skills in framing questions, id-

---

Figure 1. Map of 1997 and 2000 Pacific Northwest earthquakes. The final map was the result of superimposing the layer of 2000 earthquake data (a) to the 1997 earthquake data and plate boundaries layers (b) to a layer of state lines (c).
identifying the data needed for effective analysis, and drawing conclusions based on that data.

In each of these three learning components, it is important to note that student-centered activities do not imply that the teacher becomes a simple spectator. If anything, the teacher’s role becomes greater in an inquiry-oriented class such as this (Bednarz, 2000). To reinforce this notion, the authors worked diligently to model this active engagement with the class. In supporting hands-on investigations, the teacher must be aware of how students are processing what they are observing, being vigilant to counter misconceptions as they emerge and to ask the probing question at the right time that extends students’ understanding. Likewise, teachers need to guide student’s efforts to locate, download, and interpret online data. As this is often an area of relative weakness for students, it is essential that the teacher leading the investigation be both familiar with basic data analysis techniques and familiar with the science behind the data (Feldman et al., 2000). Teachers facilitating effective use of GIS need to be resourceful in how they prepare their students for inquiry, in addition to needing a fair proficiency in GIS skills. Bednarz (2000) offers helpful guidelines to support efforts to design Problem-Based-Learning GIS activities that have significant academic content.

Clearly, the three-part framework described above is a challenging one for teachers. To simultaneously enhance their own understanding of earth science concepts, integrate new technologies, and move toward inquiry-oriented pedagogy poses sizable challenges for teachers. While it would be easier to tackle only one of these areas at a time, we believe that it is essential that teachers encounter all three simultaneously, even if actual implementation in the initial stages is uneven. Simply adding new science “content” understanding without considering its use in the classroom is unlikely to lead to significant change in many classrooms. Conversely, to run an active hands-on classroom not informed by current, scientifically valid concepts leads to a classroom full of activity, but not likely to support much learning. The two have to go hand-in-hand as students use active investigative techniques to make sense of current scientific theories. When this context has been established, the use of real data and advanced analytic tools such as GIS becomes meaningful.

To support teachers’ growth along the lines envisioned here, the authors envisioned “Mapping Natural Disasters” as a week-long summer workshop with follow-up sessions during the school year for middle grades (4-8) teachers seeking to further the implementation of science and technology into their classrooms. To add specific criteria to this general purpose, we set specific objectives for the workshop, including:

1. To provide exposure to up-to-date earth science concepts relating to earthquakes, volcanoes, floods, hurricanes, and tornadoes;
2. To apply techniques of promoting inquiry and reflective practice among teachers; and
3. To facilitate the use of GIS software and data in educational settings to support meaningful inquiry.

This workshop developed as a collaborative effort of the Missouri Botanical Garden, the Missouri Geographic Alliance, and Southwest Missouri State University, and it is the most recent of a series of professional-development opportunities offered by the Missouri Botanical Garden to K-12 teachers focusing on using GIS technology. In these projects, teachers are encouraged to work with students to collect, map, and analyze data about scientific phenomena.

The workshop was held twice during the summer, with one week in St. Louis followed by one week in Springfield, Missouri. Most participants in the St. Louis workshop taught in urban or suburban schools within the St. Louis area while most of the participants in Springfield taught in rural schools within the Springfield-Branson area. In all significant regards, the
workshop content, schedule, and outcomes were the same.

We took special care in designing the workshop to model the integration of hands-on activities, data analysis projects, GIS computer exercises, and group discussions. More pragmatically, varying the type of activities throughout each day provided a much-needed balance and variety in the intellectually intense seven-hour long sessions.

HANDS-ON ACTIVITIES

Hands-on activities served two purposes; (1) to deepen participants’ own understanding of important science concepts relevant to natural hazards, and (2) to model how to structure and pace hands-on inquiry in the classroom. For teachers with little experience using hands-on approaches to science, the transition to this approach requires some experience with basic materials management and practice using discussion to build conceptual understanding (Feldman et al., 2000; Gallas, 1995). The ultimate goal is that students using hands-on science don’t simply follow a recipe to a predetermined outcome, but instead are able to reflect on their experiences and articulate their observations to their peers, under the skilled leadership of the teacher. While such growth takes time for teachers and students, it is essential that it be modeled in professional development workshops.

The hands-on activities that we selected each introduced a basic principle involved in natural hazards in an interactive manner and in a comparatively short time. A large number of publications offer ideas on science activities that relate to natural hazards, among them NSTA (1989) for earthquakes and Shevick (1998) for the properties of air involved in the development of severe weather. Throughout the hands-on activities, teachers interacted freely, sharing their own strategies to address the age-appropriateness of underlying concepts and offering ideas to modify or extend these activities in order to make them more useful for their classroom.

The following two examples are representative of those modeled at the workshop:

**Volcano Eruption** - Lava flows were simulated by pouring two types of syrups (light maple syrup and bee honey) over a tilted board that had a grid drawn on it. The ability to flow was measured by how fast the syrup advanced down the board, easily measured by counting the spaces on the grid, and this was related to viscosity of the syrup. The viscosity of the magma was then associated with the shape and size of the volcano, and to its explosiveness. Participants were led in a discussion of underlying concepts such as which of the two types of magma would produce a more violent explosion, which one would travel farther, and how the cooling of the lava would affect its flow. After the core activity was completed and discussed, teachers commented about possible extensions, like building in explicit math activities such as measuring the area covered by the syrup or the time needed to reach the base of the board.

**Caldera Formation** - A related activity demonstrating the formation of calderas in contrast to volcanic cones came next. Participants placed an inflated balloon inside a box and completely covered it with sand. When the balloon was popped, a depression formed on the surface. The discussion centered on the formation of calderas based on the size and shape of magma chambers, presence of faults, and other factors. Because the depression formed in our sand box was not very well defined, additional comments from the participants focused on procedural matters concerning how to obtain a better demonstration by varying factors such as whether the sand should be wetter or drier or if the balloon should be a different size. This dual focus on science content and pedagogy was reinforced throughout all workshop activities.

**Cloud in a Jar** - In this well-known activity, a glass jar is filled one-fourth full with hot water and ice is placed on top (an inverted lid can be used to this purpose). The air inside the jar saturates and a fast-moving cloud starts to form. The cloud is better seen after adding smoke (by throwing a lighted match inside the jar) and by placing black construction paper behind the jar. After some time observing and “perfecting” their cloud, students responded to questions about how these conditions are satisfied in nature, what does the hot water represent, why did the cloud become visible after the match was introduced. This activity was complemented by...
measuring the relative humidity inside and outside the room using a sling psychrometer and by reading the change in barometric pressure. Luckily, there was a storm approaching that gave more meaning to both instrument readings and accompanying discussion.

INTERNET RESOURCES

The Internet offers many outstanding web sites on natural hazards, including informational sites focusing on public awareness and disaster protection, databases from universities and government agencies, sites featuring lesson plans for teachers, and a wide variety of sites designed by private citizens who are captivated by this topic. Given this wide variety of sites include those created by "amateurs", it is particularly imperative to remind students to be critical of the accuracy and validity of the information presented in a web site. Many of these sites contain background information about specific events and/or data that students can analyze in a GIS (Table 1). For example, the Storm Prediction Center reports the location of tornadoes and other severe weather in the United States each day. Likewise, the National Hurricane Center reports the current location of hurricanes and tropical storms every 6 hours. Each of these types of data can be plotted along with archival data using GIS software as described in the next section.

Teachers worked with several of these sites and explored part of their interactive activities during the institute, with the goal of gaining an awareness of the range of resources available. In the follow-up sessions, teachers will be using selected web sites more extensively as they locate, download, and analyze relevant data. In the interest of time and to ensure that teachers were not overwhelmed with technical procedures prematurely, we provided most of the data in a "pre-packaged" form for the summer institute. To this purpose, Coulter furnished CD-roms containing the files required for our GIS exercises.

MAPPING WITH GIS

Maps help students visualize the spatial relationships of data (Curtis et al., 1999; Kerski, 2001; and Kastens et al., 2001) leading to improved understanding of earth science concepts (Orion et al., 1997). This is true because a spatial analysis of the data often reveals trends in ways which solely numeric analysis does not allow. For example, maps that show the seasonal change in where tornados strike in the United States provide a compelling basis for students to initiate a study of factors that contribute to the formation of a tornado, how these factors vary seasonally for a given location, and why Missouri is considered part of "Tornado Alley" each spring and summer.

Students who are visual learners gain particular benefit from the mapping process, as the presentation of the data is consistent with their cognitive strengths (Kerski, 2001). Until the emergence of GIS and related mapping technologies, constructing maps by hand was an elaborate, time-consuming task that often required good drawing skills. While sophisticated software takes some time to learn, computerized mapping is comparatively easy. Students with basic GIS skills can produce a high-quality map with just a few clicks of a mouse.

Table 1. Some web sites containing relevant information on natural hazards.

<table>
<thead>
<tr>
<th>Internet Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storm Prediction Center: [Link]</td>
</tr>
<tr>
<td>National Hurricane Center: [Link]</td>
</tr>
<tr>
<td>Tornado Project: [Link]</td>
</tr>
</tbody>
</table>

As described previously, the most relevant features of a GIS-based map are the superimposed themes (or layers), which a student can customize to reflect the properties and the range of values that best fit the project (Figure 1). For example, a student could enhance a plot of earthquake epicenters on a world map by color-coding their magnitude to show where the most severe earthquakes occur, or by color-coding depths to locate subduction zones. Once basic skills in data plotting are developed, students can select one of several map projections available from the software. Although the Mercator projection (i.e., flat map) fits most of the projects, someone may choose an orthographic projection (view from space) to better see large-scale patterns, such as plate boundaries or earthquake epicenters on global scale.

In addition to supporting the spatial display of data, students can use a GIS to support a quantitative analysis. As shown in the "top ten" lists at the Tornado Project web site (see Table 1), there are many ways to describe the most dangerous state. By mapping raw numbers of

Gutierrez et al. - Natural Disasters Workshop 441
tornados, Texas would appear on a map as the most dangerous. Once the data is “normalized” to consider factors such as deaths per 10,000 square miles, Texas doesn’t even make the top ten. (Massachusetts is first in that category—a state one does not often associate with tornado danger.) In this way, students can be led to think more critically about the data as they go beyond broad statements such as where tornados are most dangerous.

Throughout the data analysis and mapping process, we strove to model for the teachers how the data leads to an enhanced understanding of key earth science concepts. All too often technology-enhanced projects become technology-based, resulting in the learner becoming disconnected from the main focus of the investigation—in this case, the science of natural disasters. On the contrary, the maps made with GIS encouraged further inquiry as participants noticed patterns, sought out more data, and discussed the results with their peers. Going further, the interdisciplinary nature of natural disasters (e.g., analyzing health implications, risk management, determining the costs of the damage inflicted, mapping the population sectors most affected) means that students are not limited to just the scientific aspects of disasters. They can readily include other relevant information so their research project is more reflective of real world situations.

Figures 2 and 3 are example maps elaborated by participant teachers during the workshop, which were followed by their ideas on how this activity would address one or more of their curriculum requirements.

**REFLECTIONS AND NEXT STEPS**

Based on the success of the workshop in enhancing teachers’ understanding of key earth science concepts (31% improvement, obtained by means of pre-test/post-test data as shown in Table 2), we feel that the model presented here is sound. By starting with an engaging topic, and from there enhancing understanding through hands-on inquiry and background readings, teachers were better able to interpret and map relevant data sets. Subsequent research (to be conducted by Dr. David Goodwin once longer term implementation information is gathered) will document the implementation level of what was learned in the summer institute and follow-up sessions. To further support teachers’ implementation efforts, four follow-up workshop days have been scheduled.

Of the three pedagogic components presented here (hands-on activities, authentic data sets, and GIS), the GIS-based analysis is by far the most novel in school settings. As noted above, the Education Division of the Missouri Botanical Garden has been working with teachers on the integration of GIS into environmental investigations since 1999. This was, however, the first year in which teachers made use of GIS tutorials designed by the Missouri Botanical Garden explicitly for use by middle school teachers and students. Previous cadres of teachers helped to shape these units, but they were not ready for use as introductory modules. We were gratified both by the quality of maps prepared by the teachers and by the summative feedback provided by teachers at the end of each week-long institute.

Throughout the Institute, participants were intrigued with the uniqueness of each event and on how the recurrence of events still defies prediction, even with the great advancement of science. This can be frustrating to those students who think that science has an answer to all natural phenomena. By comparing events, trying to find an explanation and predict the occurrence of future natural disasters, teachers experienced the inquiry-based approach emphasized so strongly by the National Science Education Standards (1996).

Natural disasters proved to be an engaging topic and participants were excited about the possibilities of integrating GIS technology into their classroom, evident

<table>
<thead>
<tr>
<th>No. Participants</th>
<th>32</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. questions*</td>
<td>35</td>
</tr>
<tr>
<td>Max. possible score</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Median</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>% improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>55</td>
<td>75</td>
<td>31</td>
</tr>
<tr>
<td>Mean (Std Dev.)</td>
<td>53(22)</td>
<td>75(9)</td>
<td>72(93)</td>
</tr>
</tbody>
</table>

* multiple-choice questions on fundamental earth science concepts related to natural hazards (GIS or technology-related questions were not included here)
by their attendance and great participation. Participants with no previous exposure to GIS were able to produce high-quality maps and tie them to earth science after a few days of training. We are convinced that GIS technology is a great addition to teaching of earth science. More workshops are needed to reach more teachers, as GIS is not yet introduced in most teacher preparation programs. Continuing research will also be needed, to document obstacles and successful implementation strategies.

ACKNOWLEDGEMENTS

This project was made possible by an Eisenhower Professional Development grant from the Missouri Coordinating Board For Higher Education and through funding provided by the Litzsinger Road Ecology Center in Ladue, Missouri. Special thanks go to ESRI for providing ArcView GIS software and site licenses at no cost to participating schools, and to Southwest Missouri State University for waiving the cost of graduate credits for participants. We also thank workshop participants for their thoughtful feedback and for allowing us include some of their final projects in this article.

REFERENCES

Coulter, R., 2001, Helping students make the best use of the Internet, Principal, v. 81, p. 59-60.