The dedicated use of seismometers for the leap-frogging arrays and the offshore complement to EarthScope will require the construction of additional OBS, which could be handled by the existing OBSIP facility. In addition, at present, the seismometers are typically deployed by allowing them to free-fall from the sea surface to the ocean floor, and hence the quality of the seismometer installation is subject to chance. Because the seismometer sits on rather than beneath the sea floor, even modest sea floor currents (~1 cm/s) can tilt or rock the instruments slightly, creating noise that causes the horizontal-component data to be of limited usefulness for teleseismic studies at periods longer than about 20 s. Burial of the seismometer in the seabed to a depth where the top of the seismometer is flush with the sea floor greatly reduces this tilt-generated noise. An efficient means of shallow burial of the sensors will have to be developed.

More information about the proposed Ocean Mantle Dynamics Initiative can be found at http://www.whoi.edu/science/GG/omd/, including a science plan and an implementation plan.

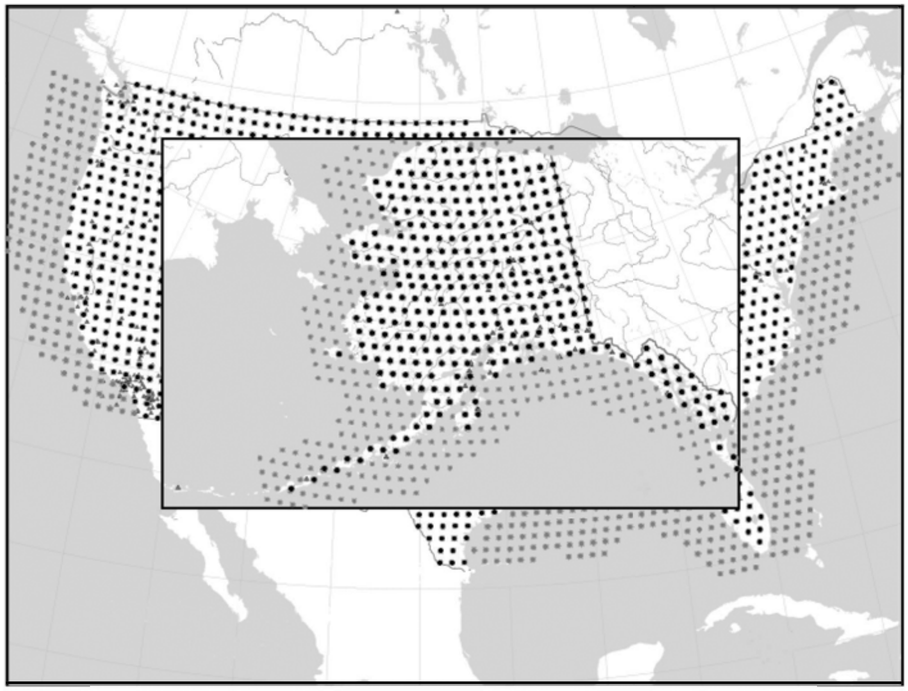

Fig. 3. USArray Bigfoot stations (black dots) and proposed Webfoot offshore ocean bottom seismic array (gray dots), which would move with USArray around the margins of North America are shown. As recommended, Webfoot would consist of ~150 OBS spaced 70 km apart extended ~600 km offshore.

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Investigation-Stimulated Discussion Sections Make Geoscience More Relevant in Large Lecture Class

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Have you ever posed a question to a large introductory lecture class and been greeted by silence in return?

Do you look out across the lecture hall and find half the seats empty on an average day?

Do you ever walk out of class feeling like you taught the material well but they just didn't get it?

At the University of Vermont, we've tried to change this picture. Using educational research to guide us [e.g., *McNeal and D'Avano*, 1997], we developed—and are now teaching for the fourth time—an introductory course specifically designed to engage students and hold their attention by continually demonstrating the relevance of science to their lives and society in general.

Our class, Earth Hazards, is taught using interactive, technology-based, student-centered lectures that increase student interest and involve students in the learning process. Earth Hazards lectures are paired with required weekly 50-minute investigation-stimulated discussion sections, in which students get their hands dirty and work with their peers to consider scientific problems that are relevant to their lives and interests. This article describes these sections and demonstrates how they have helped increase the engagement of predominately non-science students in this large introductory class.

Defining the Problem, Identifying Solutions

Introductory geoscience classes are traditionally taught to mostly non-science majors in a large lecture setting. Many of these students go on to become political, business, and community leaders whose lives and decisions affect everyone, so helping these future citizens understand the role and utility of geoscience in society is critical. Indeed, more effective curricula and teaching practices that improve science education are a national priority [*Goldsmith*, 2002].

Education research shows that a more engaging class format involving group work, interactive demonstrations, and other techniques can improve student attitudes toward and involvement in the material, and thus benefit student learning [e.g., *Yuretich et al.*, 2001]. In addition, optional honors seminars can be used as an adjunct to large lecture classes, to increase the interest level, learning, and performance of students who choose to take such a seminar [*Miller*, 2002]. With the Earth Hazards course, we have taken the next step: requiring students to participate in discussion sections, so that all may benefit from the engagement and experiences these sections provide.

What are Discussion Sections? What is Discussion?

It is important to define "discussion" and its role in the Earth Hazards sections. Discussion in this context is a specific instructional strategy used to engage students in analysis of information, to assess levels and types of student understanding, and to promote student voice and relevancy. The benefits of such discussion can only be fully realized when the facilitator plans essential questions in advance. Proper questions encourage students to consider what they know and how they have come to know it. The goal of discussion is not to uncover a "right answer," but for individuals to explore personal assumptions, beliefs, and understandings. Prior research shows that discussion can make learning more meaningful, engaging, and relevant [e.g., *Garmston and Wellman*, 1988], as our course surveys confirmed (see below). In our sections, we focus discussion on student ideas and opinions about the roles and effects of natural disasters in society, such as the formulation of government policy, public responses to disasters, and personal choices in relation to these events. Short, hands-on, investigative activities are used to stimulate these discussions.

How Do the Sections Work?

The discussion sections complement the biweekly lectures, which cover a variety of natural disasters. The class meets twice a

By Eric M. Butler, Paul R. Bierman, and Rebecca H. Gajda

week (90 minutes each) in a large lecture hall. Class enrollment was 220 students in 1999 and 2001, but was cut to 140 in 2002. Required 50-minute discussion sections are led weekly by teaching assistants (TAs), who guide students through 30–40 minutes of small-group activities. We engage students using hands-on modeling, analysis of real geologic data, exploration of historical images, reading of persuasive articles, and personal expression through artwork and writing (Table 1). These investigative activities lead into a 10–15 minute discussion, in which the TA facilitates an exchange of ideas among the students, guiding their questions and responses to investigate important relationships between science and society.

For example, students model mass movements by dripping water onto mounds of sand poised precariously on sloping wooden ramps, using Monopoly houses to represent a human presence (Figure 1). The resulting slides allow them to experience first-hand what mass movements look like, as well as relate this phenomenon to its effects on buildings in slide-prone areas. Activities such as this provide an effective impetus for students to discuss how development, government regulation, and economic incentives interact with geologic forces and thus contribute to the magnitude and distribution of natural hazards. Rather than just present another lecture or reading assignment on these issues, we provide our students with a setting in which they can investigate these issues as a group, thus teaching themselves.

What Makes Discussion Sections Work?

The combination of student-centered investigative activities and facilitated discussion is key to the success of these sections; either method on its own would be less effective in stimulating student interest and thought. The activities are chosen not to teach specific information or skills, but rather to engage students in exploring links between science and society. Our goal is not to produce scientists, but scientifically aware and engaged citizens. For example, when we present students with historic depictions of the 1755 destruction of Lisbon, Portugal by a combination of earthquakes and tsunamis, we are not teaching art history, but helping them better understand the interaction between natural disasters and human society. We found that 250-year-old images of Lisbon in flames effectively encouraged student discussion about what such an event could do to a modern city, and how people could/should respond.

Sections use a combination of engaging activities and facilitated discussion to help students make personal connections with the material and explore links between science and society. We defined sections for Earth Hazards as discussions rather than laboratories for several reasons. We wanted to engage non-science students who would never take a lab course, and wanted the class to maintain a 3- rather than 4-credit status. Our discussion sections share common elements with laboratory sections, in terms of investigative activities that involve measurement and observation, but shift the emphasis from "doing the experiment" to understanding larger themes and stimulating interaction and discussion.

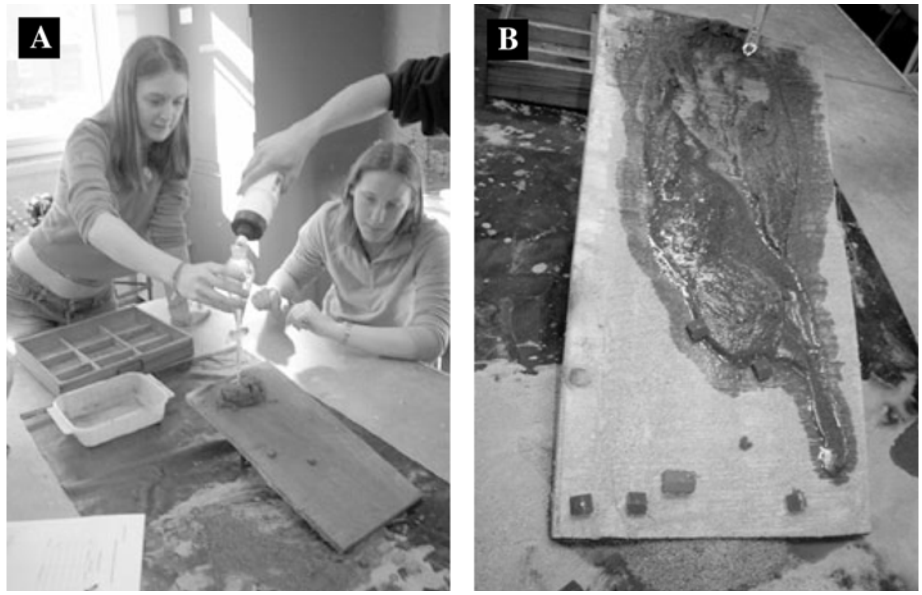

Fig. 1. Hands-on modelling of mass movements is used as a catalyst for student discussion. (A) Students drip water onto moist sand in order to initiate a flow down the wooden ramp. (B) A flow engulfs local infrastructure (Monopoly houses). Such activities help students build connections between geoscience and their own lives.

Why Use Discussion Sections?

Discussion sections improve the class experience in many ways. They provide students with an opportunity to engage further with the material; activities and discussion allow students who are not comfortable learning through lecture alone a chance to learn in different ways. They can make connections between science and their own lives and interests; many of our activities involve art, journalism, economics, and other subjects

Table 1. Brief Description of Discussion Section Topics and Activities.

Subject	**Activity**
Earthquakes	Read journal and newspaper articles about economic & political issues surrounding earthquake insurance.
Volcanoes	Calculate eruptive recurrence intervals for six Ecuadorian volcanoes.
Hurricanes	Plot & compare tracking data for eight major Atlantic hurricanes on a map.
Mass movements	Model mass movements using wooden ramps, sand, and water.
Floods	Plot and compare cumulative precipitation data and discharge from Vermont rivers.
Avalanches	Use avalanche transceivers to locate a buried "victim."
Bolide impacts	Model bolide impacts by shooting small rocks into trays of flour and sand.
Tsunamis	View and analyze historic artistic depictions of the 1755 devastation of Lisbon, Portugal, by a large tsunami.
Climate change	Create artwork depicting facts, ideas, or opinions related to human-induced climate change (assigned ahead). Present and explain artwork to class.
Nuclear issues	Write short research paper based on collection of photography depicting the nuclear era (assigned ahead). Present topic of research to class.

about which students are already interested and knowledgeable. Because sections are graded only on attendance and participation, students can be interested and involved in the activity and discussion without worrying about "getting it right" or "learning what will be on the test." Finally, sections help build personal relationships between faculty and students; the TA knows each student by face, name, and personality, and can give much more personalized attention than is possible in a large lecture class alone.

Effective discussion sections require strong links to the lecture portion of the course. Our sections are scheduled to take place between the two weekly lectures, so that students are introduced to material before section, investigate it during section, and then relate their experiences to new material presented in the following lecture period. As described above, our lectures are taught in an interactive manner that encourages student thought and participation, a consistent theme that carries over into each section.

Our Experience

We addressed several challenges in offering discussion sections. Many students had little experience with classes taught in this style and were initially reluctant to participate. TAs were comfortable with leading investigative activities, but unfamiliar with leading effective discussions, and early in the semester sometimes found it difficult to engage students. These problems diminished as the experience of both students and TAs increased over the semester. Our discussion section curriculum (available on our Web site; see below) includes specific guidelines for TAs, who may benefit from reading education literature on effective techniques for leading discussions [e.g., *Dillon*, 1994; and *Jackson*, 1995].

Surveys conducted at the end of the fall 2002 semester indicate that students found our class engaging—one of the major goals in designing the course. For example, when asked to rate how well the various classroom settings met their preferred learning styles, students rated our lectures at an average of 4.1/5.0, and discussion sections at a similar 4.0/5.0, suggesting that they found both parts of the class equally engaging. While the numerical evidence was positive, the written student commentary is most telling, given our emphasis on experiential learning in sections. Such feedback also emphasized the effectiveness of the class at meeting our goals of student engagement, relevance, and interest (Table 2). While most students were excited by the hands-on modeling experienced in the bolide and mass movement sections, some were uncertain about the more unusual, art-based sections, including climate change and tsunamis. However, these same sections drew strong praise from other students who commented specifically on how excited they were to be able to apply their knowledge of humanities in a science course.

Table 2. Selected Quotes from Student Evaluations, Post Fall 2002 Semester.

I have learned a lot from discussion sections; they clarify what we learn in class and keep the info fresh in our minds.

I love the structure of this class; it makes me interested in the material and I appreciate how approachable and enthusiastic the professors and T.A.s are.

I have enjoyed this class because the teachers make constant efforts to make everyone understand the materials. They also try and reach out to all learning styles, which I know is greatly appreciated.

I really enjoy the class – it uses a very different teaching style that is engaging and interesting. It is very interactive. Keep up the good work!

I really feel like the instructor and T.A.s care about how the students in this class are doing, and this is a very different atmosphere from most lectures. BRAVO!

The discussions were really good at getting opinions that I never would have heard without the sections.

Discussions allowed us to really think about and incorporate what we learned in class. Rather than just learning the stuff we actually got to do something with it.

I think I would have learned the same amount or even less in a class with someone talking at me the entire time, but I think the knowledge that I gained here will stay with me longer because I have experiences to connect it to.

Personal interactions with students also suggested that our methods worked for increasing student interest in the course. Students generally came to class on time and rarely left early. While our average attendance on quiz days was slightly higher than before we instituted sections (rising from 93% to 95%), our average attendance on non-quiz days rose dramatically (from 74% to 82%). Overall, average class attendance rose from 83% to 88%, an excellent result when compared to the 80% attendance rate cited as success by *Yuretich et al.* [2001]. The students were not the only beneficiaries; faculty and TAs felt that the fall 2002 semester was one of the best teaching experiences they ever had, and actively look forward to offering the class again. Many students sought us out for further discussion of the material on their own time, even after the semester was over, and we were repeatedly asked, "why can't all classes be taught this way?"

Although our curriculum was developed around a subject (natural disasters) that easily lends itself to student discussion of issues, the methods could be adapted for use in many classes to produce a body of students who view geoscience as interesting and relevant. Based on our experiences, we strongly recommend the use of investigative activities and discussion in introductory geoscience courses.

To learn more about our methods and curriculum, visit our Web site: http://geology.uvm.edu/morphwww/classes/ehaz/hazinfo/index.html.

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