From Local to EXtreme Environments (FLEXE): Connecting Students and Scientists in Online Forums

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1 Introduction

Science education reform efforts in recent years have called for a “new way of teaching and learning about science that reflects how science itself is done, emphasizing inquiry as a way of achieving knowledge and understanding about the world” (NRC 1996, p. ix). Scientists and engineers, experts in scientific practice, have been called upon to help model these practices for students and to demonstrate scientific habits of mind. The science education research literature includes a number of rich, project-specific descriptions of beneficial outcomes when scientists and students work together (e.g., Hsu and Roth 2010; Rahm et al. 2003; Rock and Lauten 1996). Questions abound, however, concerning how best to involve experts, given the very real challenges of limited availability of scientists, varying experience with effective pedagogy, widespread geographic distribution of schools, and the sheer numbers of students potentially involved. Technology offers partial solutions to support some student-scientist interactions (SSIs). Our international environmental education project has developed online forums to support SSIs, making use of web and database technology to facilitate communication between students and scientists (Kerlin et al. 2009). We approach questions of design and efficacy scientifically, including the use of randomized trials, explicitly testing the effects of SSIs on student learning and attitudes toward science.

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V.C.H. Tong (ed.), *Geoscience Research and Outreach: Schools and Public Engagement*,
Innovations in Science Education and Technology 21, DOI 10.1007/978-94-007-6943-4_6,

Forums in our project are designed to showcase scientific practices and habits of mind through facilitated interactions between students and scientists. Through these online forums, students “meet” working scientists and learn about their research and the environments in which they work. Scientists provide students with intriguing real-life datasets and challenge students to analyze and interpret data through guiding questions. Students submit their analyses through the forum, and scientists provide feedback and connect key concepts and instructional activities with real-life scientific practices, showcasing their activities in the field. Forums are embedded within inquiry-based instructional units focused on essential learning concepts and feature the deep-sea environment in contrast to students’ local environments, in order to strengthen students’ understanding of earth systems processes.

2 Context

FLEXE is the NSF-funded project, “From Local to EXtreme Environments: Deepening Earth Systems Science Understanding with GLOBE” (NSF #0627909, Directorate for Geosciences). FLEXE is a collaboration among GLOBE, the NSF-funded Ridge 2000 research community, and researchers from Penn State University. GLOBE (Global Learning and Observations to Benefit the Environment) is an international environmental education program that engages teachers and students in investigations of diverse local environments. Ridge 2000 facilitates the interdisciplinary research of an national network of scientists that studies deep-ocean hydrothermal vents, where geological and biological systems are unusual (e.g., in these settings, chemosynthesis is the basis of the food web). The FLEXE project has used the GLOBE and Ridge 2000 networks to connect teachers and students from six different countries (USA, Australia, Costa Rica, England, Germany, and Thailand) with deep-sea scientists in studies of local and remote environments.

In FLEXE, middle-school-age students investigate a familiar terrestrial environment and compare their findings to data from both a partner school (elsewhere in the world) and a deep-ocean site. To date, more than 3,500 students have participated in FLEXE projects. Each project entails 20–25 days of lessons, including fieldwork, laboratory activities, other classroom instruction, and work on computers.

FLEXE projects include some student activities that are common in contemporary science instruction:

- Teacher-directed instruction
- Protocol-driven laboratory and field investigations
- Small group work to analyze data and reach conclusions

And some that are fairly unusual:

- Comparison of local data with data collected by students elsewhere in the world and with data collected by scientists, through structured, web-based interactions
- Peer review of research findings from fellow students and response to peer feedback

- Communication with scientists, through responses to questions that direct students to compare terrestrial environmental investigations with research in deep-ocean settings

We have developed and implemented two instructional projects: one focusing on the flow of energy and one on ecology.

3 The Energy Project

The first project developed by FLEXE focused on energy transfer in terrestrial and deep-ocean environments. Students completed a number of learning activities, including a web-based multisite comparison of seasonal and diurnal temperature variation, examination of deep-sea extreme temperature patterns, and an empirical study of temperature variation in students' own schoolyards. The latter activity culminated with student submission of research reports, followed by web-based peer review of reports that involved students at schools elsewhere in the world. Students also read narratives about deep-sea research, viewed slideshows and video clips from the deep-ocean setting, and participated in four interactive FLEXE forums, designed to facilitate student-scientist interactions (SSIs, discussed below). Several project activities, including webcast phone calls and ship logs, were carried out during Ridge 2000 research cruises and involved shipboard scientists and other ship personnel.

The Energy Project was piloted twice: first in 2007–2008 with several hundred US students and second, with additional activities and both US and non-US students, in 2008–2009. The 2008–2009 project involved 1,419 students and 47 teachers. Teachers were recruited with the assistance of the GLOBE Program and received training through Adobe Connect sessions and on-site workshops that we offered in the teachers' countries.

Analysis of student outcomes in this phase included the systematic comparison of students' written arguments as a function of their placement in one of two randomly assigned treatment groups: one in which American science classrooms were partnered with other American classrooms (the "domestic" treatment) and one in which they were partnered with classrooms from elsewhere in the world (the "international" treatment). Students submitted and received peer feedback within these treatment groups, and forum activities (discussed below) required students to compare their local data to data from their partner school, as well as to data from the deep-sea environment. Content analysis of students' written work included both broad exploratory data analysis of the use of a wide range of "evidentiary argumentation components" in a sample of student responses and multi-coder analysis of down-selected components using a separate set of 661 written arguments (responses to one of the forums). This two-stage process disclosed several modest advantages of the international treatment, including better outcomes in written student-student interactions (Kerlin 2009) and student-scientist interactions (Kerlin et al. 2011). Specifically, in their written arguments, students in the international treatment wrote

FLEXE : From Local to Extreme Environments

FLEXEFORUM

Dataset 1: Animal Distribution with Temperature

Featured Scientist:

Dr. Chuck Fisher
Deep-sea Biologist

I study animal communities found in the deep-sea.
Read more...

Greetings GLOBE students! My name is Chuck Fisher and welcome to the first Forum in the FLEXE Ecology Unit. I'm looking forward to working with you as you begin your exploration of extreme ecosystems on the seafloor.

I'm a deep-sea biologist and I study animal communities living at places like the hot hydrothermal vents found along seafloor plate boundaries and at cold, hydrocarbon seeps found in the Gulf of Mexico. The animal communities in both of these environments are some of the most interesting in the world because they are so unique. And traveling to these places, using submersibles like *Alvin* and the ROV *Jason*, makes our work all the more challenging and fun.

In this first FLEXE Forum, we'll explore the hydrothermal vent ecosystem in the western Pacific. Specifically, we will look at data from our study site in the Lau Basin, near the Kingdom of Tonga. (Click here for more information on this study site location).

Vent Ecosystem Characteristics

Vent environments in general are
characterized by extreme conditions (e.g

What's going on:

Scenes from the Extreme

R/V Thompson at

Jason II, the remo
operated vehicle
(ROV), being laun

Lau Basin Animals:

Snails and mussel

Shrimp

Fig. 1 Screen shot of a student's view of a FLEXE student-scientist forum. This and other pages can be explored at http://www.flexe.psu.edu/main/Ecology_unit.cfm

a higher percentage of correct scientific claims, provided more evidence to back those claims, and more commonly used some specific argument strategies, such as the presentation of quantitative comparisons. The advantages of the international treatment appear to include both audience effects (related to the rhetorical challenge of communicating with students from another country) and data effects (the analytical challenge of comparing climate data with not just the deep ocean but also another terrestrial site, which might be, e.g., in another hemisphere).

Energy Project forums: There were four student-scientist forums in the Energy Project: (1) a water column temperature profile study with Dr. Matt Smith (University of Florida), (2) a longitudinal vent fluid temperature investigation that included volcanic anomalies with Dr. Karen Von Damm (University of New Hampshire) and Dr. Margaret Tivey (Woods Hole Oceanographic Institution), (3) a mid-Atlantic-vent plume "elevator ride" with Dr. Peter Rona (Rutgers University), and (4) an analysis of East Pacific Ridge faunal spatial distribution as a function of temperature with Dr. Chuck Fisher (Penn State University).

The Energy Project forums used a common format. A media-rich website introduced the scientist and his or her research in an engaging and human fashion (see Fig. 1), with the goal of interesting students in both the scientist and his or her research, a task made easier through the selection of research led by diverse, personable individuals who have interest in public outreach. Each forum website included a set of oceanographic data for students and a clearly described analysis task, broken down into developmentally appropriate steps. Depending on the forum, data were textual, quantitative, spatial, graphical, and/or photographic. For example, the faunal distribution forum dataset (#4 above) included high-resolution photographs of complex seafloor communities, with image tags showing species identifications and spot temperature measurements.

Using the scientist-provided datasets, students worked in pairs to analyze data and respond to a series of questions provided on printed worksheets; then, under their teachers' direction, they logged onto the FLEXE website and sent responses to the scientists. All of these steps were completed asynchronously within a time frame that was intended to balance teacher curricular flexibility, scientist availability (to review student answers and provide feedback), and the need for timely feedback to students.

After student responses were posted to the forums, FLEXE program staff worked with scientists to prepare scientist feedback to students, delivered through a lengthy follow-up web page. This feedback included both general responses to student ideas and numerous attributed classroom-level responses, such as "It is important to know if we are seeing something unique to one area or a general pattern. Kudos to students at the Nimitz School in Texas, who also suggested looking for similar patterns in other places in the ocean!" The preparation of this feedback involved collaboration between FLEXE staff and collaborating scientists, both to ensure that feedback was appropriate for an international middle school audience and to save time for the scientists, who were usually juggling other demands, especially when forums occurred during cruises.

Evaluative feedback to us from teachers and students in the Energy Project included students' written work, students' responses to formative evaluation questions (both subject-matter related and attitudinal) that accompanied each online activity, and follow-up surveys and telephone interviews with teachers by our external evaluator, Dr. Nancy Trautmann of Cornell University. Students eagerly anticipated each scientist's responses to their work, even when the responses were attributable to only the classroom level (because of human subjects considerations, although we tracked student responses via anonymous user names, only the classroom teachers could associate those user names with actual students). In fact, "reading scientists' responses to student questions" was annually reported by teachers as one of the most significant project components in contributing to student engagement and motivation. For this reason, we decided to look more systematically at the role of personalized scientist feedback in the next FLEXE project.

4 The Ecology Project

The second FLEXE project combined ongoing attention to the physical conditions of geologically "extreme environments" (with respect to temperature, pressure, and the presence of naturally occurring toxic chemicals, all characteristic of mantle-spreading zones and hydrocarbon seeps) with education about ecological research.

In this project, the objective was to help students deepen their observation skills and develop testable research investigations in their local environment by introducing students to ecological research in "extreme" environments. Through new instructional activities and a series of forums that featured novel datasets coupled with ongoing communications with scientists, we challenged students to consider the relationship between geochemical processes, abiotic factors, and the organisms that live in unfamiliar settings and then apply what they learn to their local, familiar environment. Ecological concepts explored in this project included animal distribution patterns, primary productivity through photosynthesis vs. chemosynthesis, symbiosis, evolutionary adaptation, trophic relationships, succession, and biodiversity.

Having previously established—at least for our needs—the better outcomes of the international treatment in student communicative partnerships, we turned our research attention in the Ecology Project to a different question. For the 2009–2010 Ecology Project, we randomly assigned all participating classrooms to one of two treatments: a "personalized scientist feedback" treatment and a "non-personalized feedback" treatment. Students in the latter treatment would receive scientist feedback that was substantively identical to the personalized feedback, but without references to the work of students in specific classrooms. Our objective with this comparison was to evaluate the feasibility of running future FLEXE projects in an "archived mode," that is, not in conjunction with concurrent Ridge 2000 research cruises and live scientist feedback.

Ecology Project forums: There were three forums in the 2009–2010 Ecology Project, which engaged more than 1,100 students and 43 teachers worldwide. The subject matter of the three forums concerned methods of spatial ecological research, adaptation and symbiosis, and biodiversity. The mechanics of the forums were similar to those of the Energy Project, with the one difference being the varied nature of the scientist feedback.

To compare the effects of personalized and non-personalized scientist feedback, some 4,198 student responses to forum questions were content analyzed. Two dimensions of responses that were systematically assessed were *response focus* (the extent to which the student addressed the scientist's question) and *response accuracy* (the extent to which the response was scientifically justifiable, given the data provided by the scientist and data provided at the school level). When the responses to all three forums were combined (in order to maximize statistical power), a statistically significant advantage was observed for the personalized treatment over the non-personalized treatment for both response focus and response accuracy (Petersen-Pereira 2011).[1] The personalization of scientist feedback appeared to make a difference in motivating students *and* in the quality of the work that they submitted to our forums.

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[1] Given international variation in school calendars and other factors, teachers were not always able to have their students submit their forum responses within the project time frame. When a classroom posted its forum responses after the deadline, those responses were excluded from the above-described analysis. As a result, we have entire classrooms of missing data for each of the forums, and those holes in our dataset obviously interact strongly with "teacher/classroom," which is usually a strong predictor of outcomes in educational research—often stronger than the treatment effect. Isolating the effects of treatment, forum, teacher/classroom, and their interactions is a complicated statistical story that we are still unraveling.

5 Implications for Practice

Projects that involve student-scientist interactions have implicit challenges. The first is how to engage scientists effectively. The Ridge 2000 community of scientists has a 30-year history of sharing amazing discoveries made at mid-ocean ridge environments with public audiences (Goehring et al. 2012), including several projects that have specifically targeted teachers and students (e.g., the REVEL Teacher at Sea program, the Dive and Discover expedition website, the Extreme 2000 website series, and the Student Experiments At Sea project). Collectively, these efforts established that ship-to-shore communication with schools can provide web-based access to scientists at sea and to the deep-sea environment, which is very engaging for students. Many of the researchers involved have reported great personal satisfaction gained through their experiences with these projects, often as a result of the reflected enthusiasm of participating students and teachers. However, unless educational projects address classroom issues such as integration with educational standards or target appropriate levels of understanding, these projects are not useful to most classrooms of today (Goehring et al. 2005). Research scientists are not necessarily knowledgeable about precollege pedagogy. Effective scientist engagement in education means focusing the project on addressing students' needs, such as understanding the larger context within which research findings fall and developing scientific thinking skills. In FLEXE, we developed materials through collaboration between scientists and educational experts.

A second challenge concerns scalability. Scientists are busy people whose participation in K-12 outreach is usually secondary to their other duties, like research and teaching. As a project grows from a handful of students to hundreds or thousands, *scientist time* is inevitably a limiting resource. Again, we addressed this in part by employing education professionals to read through student responses, assessing their understanding as well as misconceptions, and helping write appropriate responses. To facilitate the review of so many student writings, we developed database tools to allow scoring and sorting and annotation of student responses.

As a possible next step, we have storyboarded, but not yet tested, database tools that engage participating teachers in the down-select of student work, for closer scrutiny by scientists. The idea is that after students respond to a scientist's question posed on an online forum, teachers would have the option to review their own students' responses and flag responses that are representative, interesting, or otherwise worthy of further scrutiny. The task at our end would thus be reduced from sifting through thousands of responses (a large number of which may be very similar) to reviewing a much smaller number that have been pre-filtered by teachers. This could be an effective way to both down-select and involve teachers in a meaningful way, with minimal overhead. Yes, it would effectively shift some of our work to the teachers, but our experience in FLEXE has been that effective teachers do this kind of preliminary review anyway, as part of their routine evaluation of student work. More importantly, the limited resource of scientist time could now be used more efficiently. It is less likely that an especially insightful student idea would be overlooked.

A third challenge concerns the need for educational infrastructure. The oceanographic research carried out by Ridge 2000 could not be done if its individual funded scientific projects had to locate, schedule, provision, and operate their own ocean-going research vessels, satellite communication systems, submersibles, and so on. We suggest that a similar shared-services philosophy is worth considering for educational outreach operations, especially for projects that engage scientific networks. The web-based forum tool that we developed may be useful to other scientific outreach initiatives, and, in fact, we are currently working closely with the principals of another NSF earth systems science education project to evaluate its use there (Jona et al. 2006). After that, the future of the tool is uncertain; it may become a ship without a scheduled cruise. How an educational infrastructure for outreach would be funded is one of many questions that would need to be considered, but it is inarguably inefficient that so many outreach operations associated with scientific research literally start from scratch in building methods for connecting scientists and schools.

Overview

Status Quo and/or Trends

- There is substantial contemporary interest in involving scientists in outreach to schools.
- Outreach by scientists and engineers can help K-12 students understand that science is more than a static body of established facts; science can be dynamic, social, creative, and exploratory.
- Progress in many scientific domains benefits from international collaboration.

Challenges to Overcome

- Scientists have incomplete knowledge about the needs of schools and, realistically, have limited time to understand and respond to those needs, even when they would like to do so.
- Effective science-school outreach demands active translation and accommodation between systems that are different in fundamental ways.
- Educational outreach efforts from science projects tend to reinvent the wheel; they rarely build from prior experience, in part because there are only scant opportunities to learn from that prior experience.

Recommendations for Good Practice

- Program evaluation should do more than document the effectiveness of discrete program; it should contribute scientifically sound recommendations for future interventions.
- Strategies for engaging scientists in outreach need to be realistic and use their time strategically and wisely.
- We should consider significant investment in educational infrastructure to support outreach efforts from future science projects.

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