2006-435: TERRASCOPE: A PROJECT-BASED, TEAM-ORIENTED FRESHMAN LEARNING COMMUNITY WITH AN ENVIRONMENTAL/EARTH SYSTEM FOCUS

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Terrascope: A Project-Based, Team-Oriented Freshman Learning Community with an Environmental/Earth System Focus

Abstract

In the fall of 2002, MIT's Earth System Initiative introduced Terrascope, a year-long program in which freshmen work to find solutions for complex, interdisciplinary environmental and Earth system problems; simultaneously, the students explore ways to communicate on related issues with a variety of audiences, ranging from technical experts to schoolchildren. The program involves both theoretical problem solving and engineering design/construction. A major objective of the program is to develop and nurture the students' team-building skills, and nearly all of the work is done in teams. Beyond the coursework involved, Terrascope is also structured as a learning community, fostering a communal spirit and sense of shared mission among current students and upperclassmen who are alumni of the program.

Every year, Terrascope is centered around a particular environmental or Earth system problem; the problem always includes scientific, technical, social, economic and political aspects. Students are given the problem at the beginning of the year, and at the end of the fall semester the class, as a whole, presents its solution in the form of an integrated website. The class then presents and defends the solution in front of a panel of internationally recognized experts from outside the MIT community, in an event that is webcast and also archived for later viewing. In the spring, as an exercise in design and construction, teams of students develop, design and build interactive museum exhibits to teach general audiences about the area they have been studying. The exhibits are grouped to form a comprehensive exhibit, which is then opened to the MIT community and the public at large. The exhibits are evaluated by experts from the Greater Boston museum community and by members of the general public (including classes from local schools).

Terrascope also includes two optional classes: a January-term class in which students explore how people learn in museums, and a spring class in which students develop, write, record and produce a radio program about the year's theme subject. There is also an optional spring break field trip, in which nearly all of the students participate. In addition, students gather at weekly lunches and other social events, and they have exclusive access to a Terrascope classroom, lounge, computer cluster and kitchen. Many upperclassmen who have gone through the program stay actively involved in the Terrascope community, either as Undergraduate Teaching Fellows or through Terrascope-administered research projects.

In this paper, we describe the structure and evolution of the program over the past four years, outcomes for students, and lessons we have learned in designing and implementing the program.

Introduction

The MIT Earth System Initiative (ESI) is a multidepartmental organization that encourages and facilitates research and education within MIT on environmental and Earth-system science and engineering (see http://web.mit.edu/esi for details). It is directed jointly by representatives of the Department of Civil and Environmental Engineering and the Department of Earth, Atmospheric and Planetary Sciences. In the fall of 2002, ESI established Terrascope (http://web.mit.edu/terrascope), an optional year-long program open to all entering MIT freshmen; roughly 30-40 students participate each year. Terrascope is fundamentally a learning community focused on team-building, interdisciplinary work, environmental problem-solving and communication.

Terrascopers take the usual MIT freshman-year classes, but they also are also required to take certain Terrascope-oriented classes, and they have the option of taking others as well; most of these are open only to them. Terrascope classes have certain themes in common: emphasis on teamwork; focus on an inherently complex, multidisciplinary, semester-long project; content actively driven by the students' interests and judgment; a major public presentation and evaluation of the students' work at the end of each semester; and a close, collegial relationship between faculty and students. In addition to this coursework, Terrascope includes a number of community-building and group-learning elements, such as program-wide lunches with speakers, a private classroom/workspace and kitchen, and a spring-break field trip. Upperclassmen who have participated in Terrascope as freshmen often choose to remain actively involved in the community, either informally (e.g. by attending lunches) or formally (e.g. by acting as teaching fellows for the Terrascope classes or conducting Terrascope-related research projects). Students generally identify the program as a highlight of their freshman year, both academically and socially, and they report that it has had a strong impact both on the work they choose to do as upperclassmen and on the way in which they do it. (2006 is the first year in which a Terrascope class will graduate, so we do not yet have any data on post-graduation activity.)

The authors of this paper include a co-director of ESI/Terrascope (Hodges), faculty responsible for teaching the Terrascope classes (Bras, Epstein and Hodges) and an associate director of MIT's Teaching and Learning Laboratory (Lipson) who has been conducting research on the social and educational outcomes of Terrascope and its MIT antecedents since before the program's formal inception. The program is still relatively young, but over the past four years we have collected sufficient data, both quantitative and qualitative, to begin to draw some conclusions about students' experiences within the Terrascope program and about aspects of the program that make it particularly effective. In this paper we present a progress report, in which we describe Terrascope and detail some of the lessons we have learned in conducting it. We shall concentrate particularly on the engineering/design component of the program, but we shall also place that component in the context of the Terrascope program as a whole.

Fall Semester: Solving Complex Problems

In the fall semester, Terrascope students take MIT Subject 12.000, "Solving Complex Problems," which is offered under the auspices of the Department of Earth, Atmospheric and Planetary Sciences. The subject is also known as "Mission 20xx," in which the "xx" changes every year to reflect the year in which the students are expected to graduate. (So, for example, this year's class was called "Mission 2009.") This class has been taught since the fall of 2000, before Terrascope existed; in fact, it was the success of this class that led to the creation of Terrascope, which was initially conceived as a way of broadening and deepening the experience of students who had taken Mission. Unlike other aspects of Terrascope, the subject is open to all MIT freshmen (see http://web.mit.edu/mission for more details).

At the beginning of the year, Mission students are presented with a deeply complex real-world problem and are told that they have one semester in which to come up with a solution. The problem, which always involves environmental issues in some way, is devised to be highly multidisciplinary in nature and to include scientific, technical, political, economic and social aspects. This problem and the geographical region in which it is centered become the focus of the year's Terrascope experience. Previous years' problems are summarized below:

- 2002-2003 (Mission 2006): Develop a way to characterize and monitor the well-being of the Amazon Basin rainforest, and devise a set of practical strategies to ensure its preservation.

- 2003-2004 (Mission 2007): Design the least environmentally harmful strategy for extracting hydrocarbons from within the Arctic National Wildlife Refuge, and perform a cost-benefit analysis to determine whether the hydrocarbons that could be extracted in this way would be worth the environmental damage that might result from the process.

- 2004-2005 (Mission 2008): Develop a new preservation strategy for the Galapagos Islands that unifies the current Galapagos National Park and Galapagos Marine Reserve into a single, coherent unit. Design a network of environmental sensors to support comprehensive monitoring of the islands and surrounding waters. Design an idealized habitation plan for permanent residents and visitors that minimizes impact on the Islands' ecosystems.

- 2005-2006 (Mission 2009): Develop a comprehensive plan for tsunami preparedness in the circum-Pacific region, focusing on two developing nations—one in the islands of the western Pacific, and the other on the west coast of South America. Include: quantitative estimation of tsunami risk and hazard; engineering and land-use strategies to limit impact of tsunamis on people and the environment; methods for communicating tsunami warnings and evacuating the populace; and ways to prioritize and coordinate relief efforts.

Once the problem has been introduced, it is up to the students in the class to organize themselves around it, to split into teams, and to decide how best to proceed. In contrast to most of the other classes they are taking (or have taken in high school), Mission is relatively unstructured, giving students the flexibility to work in ways that they think best and to pursue whatever topics they consider important. At first many of them are confused or even made anxious by this lack of overt guidance, but as they become used to it they generally thrive on the freedom it gives them and the degree to which their studies are directed by their own interests and priorities. Each team of students is assisted by one or two Undergraduate Teaching Fellows (UTFs), generally upperclassmen who took the class when they were freshmen. Teams also have access to a number of Alumni Mentors (MIT alumni with expertise or interest in the year's focus problem) and to librarians specifically assigned to the class by the MIT Libraries.

Students are expected to complete a number of individual assignments in Mission, but the focus of the semester is on the final product, which has two components: (1) An integrated website outlining the class's solution to the problem; and (2) A live presentation and defense of their solution in front of a panel of experts brought to MIT specifically for the occasion. The presentation, which is open to the public, is webcast live and archived for later viewing on the Mission website. Students report that they find the live presentation, in particular, to be a very important component of the class. They are pleased and excited to be presenting their work to genuine experts, and their desire to do well in that presentation motivates them more strongly than simple grades would.

January Term: Visiting Museums, Brainstorming Exhibits

During MIT's January term, or Independent Activities Period (IAP), Terrascopers have the option of taking MIT Subject 1.991, "Designing Museum Exhibits to Illustrate Earth System Science and Engineering," offered by the Department of Civil and Environmental Engineering and open only to Terrascope students. The class is meant to serve as a transition between Mission and the spring Terrascope class, in which teams of students will be designing their own interactive exhibits. Although nearly all of the students will have spent some time in science or natural history museums, very few of them will have done much structured thinking about how learning happens in museums, or about how museum-based learning differs from learning in the classroom or from a textbook. The Terrascope IAP class is a week-long, intensive experience designed to jump-start that thinking process and to lay the groundwork for the spring's exhibits.

Each day of the week, the class visits a different museum in the Greater Boston area. Students meet with museum staff (exhibit planners/designers, program and exhibit directors, educators and others) to talk about the museum's approach to education and exhibit design. Then the students break up to explore the museum on their own or in small groups, paying particular attention to how visitors interact with exhibits and what they learn from those interactions. The students look for patterns in visitors' behavior and attempt to identify features that are common to particularly successful (or unsuccessful) exhibits. Then the group reconvenes with the museum professionals to debrief, discuss what they have observed, hear the professionals' perspective on their observations and learn what the museum's experience has been with various exhibits.

Before and after each day's museum visit, the group brainstorms ideas for the spring term's exhibits. In an ordinary museum, the initial conceptual development of an exhibit is generally an intense, time-consuming task, requiring input from many members of an exhibit team. During the regular semester students would not normally be able to engage fully in such a project, having obligations to meet for other classes. But during this week of IAP the students are committed largely to the Terrascope class, creating an excellent setting in which to do this kind of brainstorming. By the end of the week, the students have developed the rough conceptual framework for approximately twice as many exhibits as the spring-term class will be able to create; the final choice of which of these to develop further will be made by the class as a whole at the start of the semester, at which point teams of students will begin to flesh out and refine the concepts developed during IAP. Exhibits must be related in some way to the problem and/or region that are the focus of the Terrascope year, but beyond that restriction it is up to the students to decide what to present and how.

The IAP class is optional, and roughly 10 students choose to take it each year. These students, who become sensitized to the issues inherent in exhibit development, are then generally distributed among the various teams created during the spring semester, so that they are able to be resources for their classmates and teammates. They also serve as the seeds of larger collaborative, multi-team efforts, since the intense IAP experience tends to bond them as a group. (It certainly helps that, like most Terrascope activities, the IAP class involves a good deal of food—the class eats lunch together every day during brainstorming sessions, and the group brings snacks to share with exhibit personnel during the debriefing that takes place at the end of each museum visit.)

Spring Semester: Creating Interactive Exhibits

The spring-semester Terrascope class, MIT Subject 1.016, "Communicating Complex Environmental Issues: Designing and Building Interactive Museum Exhibits," is offered by the Department of Civil and Environmental Engineering and is open only to Terrascope students. In this class, teams of students conceptualize, develop, engineer and construct highly interactive museum-style exhibits, which are then opened to the public for several weeks. This experience reinforces the team-building skills developed in the first semester while giving students a chance to deepen their understanding of the complex problem that is the focus of the Terrascope year. The class also engages the students in an intensive engineering/design process, the final products of which will be visited and used by hundreds of people whom the students do not know in advance and will not be able to assist.

The spring-semester class, like the fall class, gives the students considerable autonomy in deciding what they will do and how they will do it, but it does provide somewhat more structure, primarily in the form of performance milestones. Roughly every two weeks there is a milestone task of some sort for teams to complete. (For example: preliminary design proposals; working prototypes; final proposals with drawings; and a "pre-opening" exhibit, ready to be viewed and evaluated by instructors and classmates but not yet by the general public.) Thus the students, whose earlier notions of academic structure have been challenged in the fall-semester class, are able to rebuild their ideas about working within an academic structure, albeit one that permits them an unusually high degree of freedom.

At the beginning of the semester, students who have taken the IAP class describe their experiences and share the insights they have gained. Then they present the exhibit concepts they have developed, and the class as a whole discusses those concepts in the context of a broader discussion about what kinds of information are most effectively conveyed in an exhibit. Individual students submit lists of the exhibits they would prefer to work on (with topics chosen from among those developed during IAP), and those lists are used both to narrow down the final number of exhibit concepts and to divide the students into exhibit teams. For the rest of the semester they work in those teams, although teams are free to decide to merge or collaborate if they choose. As in the fall-semester class, teams are assisted by UTFs and specially-assigned librarians.

For the rest of the semester, the students engage in a typical engineering/design process, although one with a somewhat atypical end product. They develop initial plans, test those plans through the use of prototypes, develop refined plans (complete with design drawings, detailed budgets and timelines), and then implement their plans, occasionally engaging in another round of prototype-construction and testing when that seems appropriate. Each team's final product is a coherent set of exhibits on a single topic. The exhibits are installed in a public space on the MIT campus and are opened to the general public. A panel of museum professionals visits on opening day and later presents the students with a round-table critique/appreciation of the work. As in the fall-semester class, the students find this expert panel's evaluation to be extremely important, both for closure and as a way of assessing their own progress and achievement. We have recently also begun involving local high-school students in the evaluation process. The high-schoolers come to MIT mid-semester to try out and comment on exhibit prototypes, and then they and some of their classmates return at the end of the semester to evaluate the final exhibits. Their feedback is presented along with that of the museum professionals, giving the students a sense of how effective their exhibits are for a non-specialist audience.

The final exhibits often show remarkable ingenuity and creativity. Indeed, a number of them have been adopted for use either as exhibit prototypes or as demonstration models by "real" museums and aquaria. Exhibit components have included: a simulated dogsled ride (complete with audio and video); an 8-foot planetarium dome displaying a projection of a simulated aurora; a recreation of a remote tropical-rainforest research station; a walk-through model of a lava tube with an associated mechanical interactive showing how some volcanic islands form; a steep playground slide whose curving slope reflects the nearly exponential decline of certain whale species; and a series of interactive components illustrating the unique features of animals native to the Galapagos Islands (e.g. a model marine iguana that squirts water at unsuspecting visitors, inducing them to read text that explains how these iguanas shed excess salt by ejecting brine from their nostrils).

In addition to these team-produced exhibits and exhibit components, each student is expected to write a brief "Developer's Journal" every week, essentially creating a chronicle of his or her experience in the class. Students describe their progress, bring up issues having to do with team dynamics, describe their frustrations and emotional high points, and comment on the structure and content of the class. These journals, and the instructors' comments on them, are an extremely important mode of direct communication between students and faculty. They give instructors a close view of what is happening within each team, particularly during the hours outside of class time, and they provide a regular opportunity to give additional guidance to teams and individuals as the projects proceed. They also serve as a mechanism to induce students to think through their experience in a structured way on a regular basis. It often happens that the process of journal writing helps students develop new understanding of their teammates, their project or even their own work and emotional/intellectual state. And, of course, the journals are an excellent source of qualitative information concerning the operation of the class itself.

Optional Spring-Semester Class: Terrascope Radio

Terrascope students also have the option of taking MIT Subject SP.360, "Terrascope Radio," developed by the Terrascope program and the MIT Program in Comparative Media Studies. This class, through which students can partially satisfy MIT's "Communication Intensive" requirement, is an exploration of radio as a medium of expression and communication, particularly the communication of complex ideas concerning the environment and Earth system science and engineering.

In order to get a deeper understanding of how radio works and what makes for effective radio programming, students come to see radio from the inside, by producing their own program on topics related to the year's Terrascope problem and region. Student teams are issued with audio kits, including sound-gathering equipment and audio-processing software, and they are trained in the use of the kits through a series of guided exercises and assignments. Simultaneously, they spend considerable time in class listening to and critiquing listening samples drawn from a wide variety of radio sources. Students also complete a number of writing assignments designed to sharpen their analytical listening skills and to give them practice in writing for broadcast. As the semester progresses each team plans out a program, finds sources, gathers sound, conducts interviews, writes and voices narration, and does everything else necessary to produce a program. At the end of the semester the program is aired on the MIT radio station. Last year (spring 2005), the first year that Terrascope Radio was offered, the program was also licensed and aired by public radio stations in Minnesota and Ohio, and it was featured as the inaugural episode of a new series of podcasts made available by the Museum of Science, Boston. (To hear that program, go to http://web.mit.edu/terrascope/www/web_pages/curric-submenu.html/Terrascope%20Radio%20Galapagos--for%20broadcast.mp3 or visit http://web.mit.edu/terrascope and click on the picture of a tortoise wearing headphones.)

Spring Break: Field Trip

An important component of the Terrascope program is the optional spring-break field trip, a visit to the region that has been the year's focal point. (Thanks to external funding the program is able to subsidize the trip, so that students are responsible for only a relatively small co-payment; those unable to afford even that amount can usually work off the cost by assisting in the Terrascope office.) The trip provides a crucial element of "ground-truthing," giving the students a chance to see the situation in all its complexity and to meet the people who would be affected by the innovations they have proposed. Seeing the reality on the ground has a deep and lasting effect on the students, and it helps bring home to them that any solution to an environmental issue or problem must take into account the needs of local populations. The trip also provides an opportunity for exhibit-development teams to acquire useful artifacts, learn about their subject in first-hand detail, and reshape their exhibit concept to better match reality. Terrascope Radio students use the trip to find interview subjects and gather sound in the field. And, importantly, the trip serves as a bonding and unifying experience for students, faculty, staff members and UTFs, greatly enhancing the sense of community throughout the Terrascope program.

Community-Building and Continuity

In addition to the field trip, there are a number of other features that set Terrascope apart as a true learning community rather than a purely academic program. One of the most important of these involves space. Terrascope students and alumni have access to a suite of rooms in the heart of the MIT campus. These include a large classroom/meeting place, a kitchen, a lounge and a computer cluster. At almost any time of day, one can find groups of Terrascope students and upperclass Terrascope alumni gathered in the Terrascope rooms—studying together, eating, working at the computers or simply socializing. The Terrascope rooms are also the site of weekly lunches, open to all Terrascopers and former Terrascopers; lunches usually include informal talks by MIT faculty members on topics having to do with environmental issues or Earth system science.

The Terrascope community extends to the students' academic advising structure as well. Freshmen enrolled in Terrascope are divided into "advising groups," each led by a Terrascope-affiliated faculty or staff member, and each provided with one or more associate advisors—upperclass undergraduates who participated in Terrascope as freshmen. Students of course receive individual, confidential advice from their advisors, but they also meet in advising groups, either for purely social functions or to discuss common issues and concerns.

In addition to serving as associate advisors, former Terrascopers may stay affiliated with Terrascope in a number of ways. Many work as UTFs for the Terrascope classes; they often report that UTFing is at least as educational as their original Terrascope experience. Others engage in Undergraduate Research Opportunity (UROP) projects led by Terrascope faculty and generally designed to follow the Terrascope approach of team-based, student-driven inquiry. Still others remain affiliated in a less formal way, by attending lunches, spending time in the Terrascope rooms, working in the Terrascope office or helping to recruit future Terrascopers.

Assessment

So far we have given an overview of Terrascope as a whole: first semester, Independent Activities Period (IAP), and second semester. In this section we describe some of our assessment efforts. Here we shall concentrate on the engineering/design component of Terrascope, the spring-semester course (Subject 1.016). We shall also dwell briefly on the spring break field trip, which, though a component of Terrascope as a whole and not 1.016 in particular, occurs during the semester in which students are taking 1.016 and so has a strong effect on their experience in the class. A future publication will report on our assessment of other Terrascope components.

The present assessment examines three major areas:
(1) Students' overall assessment of the class.
(2) Students' experiences in the 1.016/Terrascope educational environment, including their attitudes toward:

- The active learning experiences (teamwork, the field trip, and exhibit development),
- Selected teaching and learning experiences, and
- The Terrascope community.

(3) Students' self-reported learning gains in the areas of:

- Process and content learning,
- Skills, and
- Personal development.

Methodology

The data presented in this paper were collected from students who responded to end-of-term online surveys administered during each of the first three years in which this subject was offered. (At this writing, partway through the fourth Terrascope year, we have hard data only from the previous three years.) Most of the data presented are based on responses from all three of those years. In two cases (identified in the text), data are based on only two years' responses, since these questions were not included in the first year's survey. The surveys included closed- and open-ended questions and covered a variety of topics, a selection of which are discussed in this paper. To guard against statistically significant year-to-year differences among the aggregated responses (a possibility, since the program's focus topic varied from year to year, and since instructional methods may have changed slightly over time, especially since this was a new subject), we conducted a one-way analysis of variance using "year offered" as the independent variable and found no significant differences. Among the 106 students who enrolled in the class over the three-year period covered, 80 students responded, yielding a 75 percent response rate.

Results

We present the survey data in two ways. First, we discuss frequency distributions in each of the three major topic areas. Where relevant, we include some of the qualitative comments. Second, we present a multiple-regression analysis that examines the extent to which selected variables contributed to students' overall assessment of their experience in the class.

Overall Assessment

Overall, students were very positive about the class, and about Terrascope in general. Eighty-eight percent said they were "generally satisfied" or "very satisfied," while only 12 percent said they were "ambivalent" or "generally dissatisfied" with the class (mean = 4.3; standard deviation = .84). Ninety-four percent said they "probably" or "definitely" would recommend this class to incoming first year students who shared their interests, and only 6 percent said "maybe not" or "probably not" (mean = 4.6; standard deviation = .69).

Table 1. Overall Assessment of Spring Semester Class (1.016)

Level of satisfaction with 1.016	Generally/ Very Satisfied (collapsed categories)	Mean 5-point scale	SD
	88%	4.3	.84
Whether would recommend 1.016 to other incoming freshmen	Would Probably/ Definitely Recommend (collapsed categories)	Mean 5-point scale	SD
	94%	4.6	.69

Those who were positive about their experience mentioned the following themes most frequently: friendships, community, interacting with faculty, opportunities to pursue environmental interests:

- *I have become a member of a unique group and have made lasting relationships.*
- *The experience was very exciting and helped me grow as a person.*
- *My best friends are in Terrascope, and I know many more faculty members (and they know me) than most other freshmen do, and this has opened many doors during this year.*
- *Terrascope was far and away the highlight of my first year experience. It was what gave meaning to my education in the rest of the core classes and provided a strong support community and a body of friends essential for the first years.*
- *It allowed me to find a group of students who have common environmental interest. This helps to shape my academic interest and even career path.*

Students who were ambivalent or negative about the class mentioned one particular theme – the workload and time commitment. As one student said, *"It was too much work compared to what a lot of the freshmen had and took me away from doing work in other classes."*

Project-Based Teamwork

Teamwork and collaborative group problem-solving were key components of the class. As one student said,

> *One of the most important aspects of the class was the teamwork experience. You come together at the first meeting and divide up into little subgroups. Then you somehow have to get your ideas heard in your group and get your group together and kind of cohesive on what they want to accomplish.*

To learn about students' perceptions of their teamwork experience, the survey asked students to rate their team's performance during two time periods: the first and last months of the semester. The areas rated were: efficiency of meetings, ability to reach consensus on decisions, equal sharing of workload, motivation, supportiveness, and overall team performance. As Table 2 shows, students thought their overall team's performance and individual team characteristics significantly improved from the first to the last month in every area except "equal sharing of workload." In that case, there was a significant downward shift in equal workload participation among team members. This pattern is not unexpected since the last month of the semester is very challenging for students, especially for freshmen who are still adjusting to the difficulties of balancing their classes while getting ready for final exams. (This is particularly true for MIT freshmen, who in the spring are working for letter grades for the first time; at MIT, the first semester of freshman year is graded on a Pass/No Record system, although the letter grades the students would have received are revealed to them and recorded in private, internal transcripts.) In addition, students sometimes described their teams using "tag team" imagery. At times, some students would contribute less because of their other academic pressures, so other team members would have to take up the slack. However, at other times, roles were reversed and those who had taken less responsibility would take more responsibility. When asked "Which were the biggest problems students encountered in working together as a team?" the three most frequently mentioned problems were: communication, unequal sharing of workload, and conflicting schedules. The largest improvements in performance related to the procedures of working together as a team (running efficient meetings and being able to reach consensus on decisions).

Table 2. Mean Ratings of Team Characteristics: First Month vs. Last Month
(4-point scale: 1=poor; 4= excellent)

	First Month	Last Month	t ratio	Sig (2-tailed)
Overall team performance	2.71	3.29	5.58	<.001
Supportiveness	2.86	3.25	3.88	<.001
Motivation	2.83	3.3	3.74	<.001
Equal sharing of workload	2.58	2.29	2.40	<.05
Ability to reach consensus on decisions	2.39	3.13	5.71	<.001
Efficiency of meetings	2.34	3.19	6.82	<.001

In spite of the problems that teams may have encountered, students had a positive assessment of their teamwork experience. We asked students how satisfied they were with their overall team experiences (5-point scale); 45 percent said they were "generally satisfied" and 32 percent said they were "very satisfied" (mean = 4; standard deviation = .96). [i]

- *We worked well with each other and were able to rely on one another to get things done. People did what they were responsible for, and we could trust each other to do this.*
- *We worked together pretty well; it's kind of inevitable that there are some people that put in more work than others, and we've had a few conflicts. Overall it's been a great experience.*
- *Our team was good. We had a little trouble keeping track of people, but even those who disappeared did their work.*
- *I had a lot of fun working in the team environment once I realized that this was a project and not so much a class – something that I wanted to do voluntarily and not something I was working for a grade.*

The Field Trip Experience

A major highlight of the Terrascope experience is the field trip. Even though it is not specifically linked to the spring-semester class, it takes place in the middle of the semester and so has a major impact on the students' experience in the spring class. In 2003, 2004, and 2005 respectively, students went to the Brazilian Amazon, Alaska, and the Galapagos Islands. (The 2006 field-trip site is coastal Chile, which in 1960 was affected by an extremely powerful earthquake and tsunami.) We asked students about the role the field trip experience played in extending and/or deepening the class experience; 27 percent said it deepened the experience "to a great degree" and 45 percent said "to a very great degree" (mean = 4.11; standard deviation = .99). [ii] For example, students said the field trip *"made it real for people;" "allowed us to actually see what we've studied in books for the past two months;" "gave us a chance to see an issue from the inside;"* and *" helped us gain an appreciation and enthusiasm for our project and* *our research that could never be reproduced in any other way."* Not surprisingly, satisfaction with the field trip experience was extremely high: 19 percent said they were "generally satisfied" and 81 percent said they were "very satisfied"(mean = 4.83; standard deviation = .38). In addition to the educational impact of the trip, there was a large social impact. Students emphasized the important role the trip made in strengthening connections within the community (which includes students, UTFs, faculty and staff): *"During our trip, I became so close with everyone in my group;" "I got so much closer to all the students and the teachers;"* "*It made such a huge difference to the class. We weren't at all cohesive until then."*

We wondered about the role the field trip played in encouraging students to enroll in Terrascope, so we asked students, "If the field trip had not been offered, would you still have chosen to enroll?" Sixty-one percent said "yes;" they still would have chosen to enroll. Those who said "yes" were interested in the environmental topic and liked the community and would have joined regardless of whether there was a field trip. Among those who said "no," there were two major themes. Most of those who said "no" mentioned other classes they would have preferred taking but said that going on a field trip was a special opportunity. In addition, a few said they initially signed up for Terrascope because of the trip; however, they said if they had known beforehand what they would have gained by joining Terrascope, they would have participated regardless of whether there was a trip.

Exhibit-Development Activities

The focus of the spring was the development of an interactive museum exhibit that would be opened to the public at the end of the semester. The survey asked students about their satisfaction with various aspects of their exhibit-development activities. For example, as part of the development process, teams designed and built prototype exhibits, which were tested in a variety of settings. (In all years, prototypes were tested and critiqued by instructors and other students; in one year the prototypes were also tested by visitors to the Museum of Science in Boston; in another year—and, we expect, in future years—the prototypes were tested by local high-school students.) Students were generally satisfied with the prototyping experience, and they were extremely satisfied with the experience of developing the final exhibit.

Table 3. Satisfaction with Exhibit-Development Activities

	Generally/Very Satisfied (collapsed categories)	Mean 5-point scale	SD
Prototype Development			
Designing	65%	3.69	.91
Building	68%	3.74	.82
Displaying	65%	3.71	.92
Final Museum Exhibit Development			
Designing	88%	4.15	.73
Building	91%	4.43	.69
Displaying	94%	4.24	.61

Students offered a number of comments about the exhibit development experience as a whole:

- *It definitely taught us about the ways to convey information to other people, like outside of research papers and things like that.*
- *I learned what it's like to work on a project. Like what materials you need, how to design it, what your limitations are, and how to work within a budget.*
- *It's given me a new perspective on museum exhibits. I never would have thought about how complex a problem they could be.*

Teaching and Learning Activities

Although time in class is largely spent working on projects in individual teams, students do participate in some more conventionally academic activities: at the beginning of the semester there are a few lectures on topics related to exhibit design and learning in museums; individual students submit weekly journals; and teams submit multiple versions of exhibit proposals and similar documents. Instructors comment on (and grade) the proposals, the journals, and various other assignments. We asked students to indicate their satisfaction with these activities. As can be seen the most satisfaction was for instructors' proposal feedback, while the least satisfaction was with feedback on developer's journals. (See Table 4.)

Table 4. Satisfaction with Selected Teaching and Learning Activities

	Generally/Very Satisfied (collapsed categories)	Mean	SD
		5-point scale	
Lectures on exhibit design and learning in museums	61%	3.64	.89
Developer's journals	54%	3.50	.94
Instructors' feedback on journals	48%	3.41	1.00
Instructors' feedback on proposals	71%	3.84	1.04

Self-Reported Learning Gains

Students were given a series of statements about the learning objectives of the class and asked whether they agreed or disagreed (5-point scale) that these objectives had been met. The learning objectives and self-reported learning gains fell into three main areas: process and content learning, skills, and personal development. The gains reported most frequently involved understanding design and engineering processes, learning from the hands-on experience, improved teamwork skills, and students' feeling that their increased knowledge of environmental issues will likely influence them in the future. Second in frequency of report were improved problem-solving and learning to develop one's own creativity. (See Table 5.) Improved oral and written communication skills were the least frequently mentioned.

Table 5. Self-Reported Learning Gains

	Agree/ Strongly Agree (collapsed categories)	Mean (5-pt. scale)	SD (5-pt. scale)
Process/Content Learning			
Gained appreciation of the processes that go into design and engineering	95%	4.5	.60
Learned from the hands-on experience	89%	4.3	.78
Experience of teaching others helped me learn material more thoughtfully and deeply.	68%	3.8	.88
Gained greater appreciation of global environmental problems and the science behind them.	65%	3.8	1.0
Gained knowledge about scientific, economic, and political issues	61%	3.7	1.1
Skill Improvement			
Improved teamwork skills	84%	4.1	.86
Improved problem-solving skills	75%	4.0	.85
Learned how to encourage my creativity	74%	4.0	.91
Improved oral communication skills	43%	3.2	1.0
Improved written communication skills	16%	2.7	.87
Personal Development			
[My] increased understanding of environmental issues will likely influence me in the future (no matter what major or career I choose).	86%	4.2	0.77

A question at the end of the survey asked students to comment on what they had gained from participating in the class and to describe *big* concepts or *important* skills (academic or not) that they had learned The three areas students commented on most frequently concerned teamwork, problem-solving/project management, and construction. Here are some typical comments:

Improved Teamwork and Communication skills:

- *I sharpened my teamwork skills.*

- *I learned mostly about how to work in a group.*
- *I learned a lot about teamwork and cooperation.*

Improved Problem-Solving and Project-Management Skills:

- *I learned the importance of careful planning.*
- *I learned how to make a plan and then divide up tasks so that work is done most effectively.*
- *I learned how to complete a project, even when you may not be completely in favor of it.*
- *I learned about problem solving and making a timeline, and most importantly, I learned how many different steps there were in creating a final project.*

Improved Construction Skills:

- *I learned how to build things.*
- *I learned how to create things with my hands and use tools.*
- *I feel like I know more about construction.*

Students were asked whether the class has had any influence on the way they think about themselves (their major, their career, the environment, the future, etc.). Sixty-six percent said "yes." The following are some representative comments:

Thoughts about Self

- *I believe now that I am capable of so much more than I thought. It pushes you to your limit.*
- *Influenced how I view myself as a leader.*
- *More confident I will make a difference in the future.*
- *It has made me more environmentally conscious.*
- *I've learned more about how I deal with people and the fact that I'm a total perfectionist.*
- *I did not used to consider myself an environmentalist and now I believe in the preservation of nature and the need for sustainable cooperative living.*

Thoughts about Major or Minor

- *It has confirmed my idea about studying the environment.*
- *It has made me more interested in designing and building stuff (Course 2 stuff – Mechanical Engineering).*
- *I am now thinking of double majoring in Course 1 (Civil and Environmental Engineering).*
- *I've decided I want to major or minor in 1E (Civil and Environmental Engineering, weighted towards environmental engineering) because the concepts of environmental conservation seem so exciting and important.*

Thoughts about Career

- *It has made me wonder about environmental engineering as a career.*
- *I would like some sort of career dealing with the environment.*
- *I think I want to pursue a more design-oriented career.*

- *I found that I like engineering/hands-on working.*
- *I definitely want a career that is creative and where I can solve problems.*

Development of a Learning Community

Students were asked about the sense of community that developed both during the second semester and throughout the year. Community was defined as "a group of people whom you knew, liked, and with whom you felt you shared a common bond." Seventy-two percent said the class felt like a community to a "great" or "very great extent" during the second semester (mean = 4.00; standard deviation = .91). One student summed up and explained these sentiments:

> *The individual groups allowed for very close interaction and working in the rooms allowed for some inter-team interaction. I think that knowing everyone from first semester and then having the smaller group made it easier to form better friendships. And then the creative process and the laughs and definitely the trip made everyone know each other on a much more personal level. I think building [the exhibit] allowed more time for chatting.*

The value that students placed on the community aspect of their experience was also highlighted when, in response to the question of whether "1.016 should be open to any students who would like to enroll [rather than just Terrascope students]?" 84 percent said "no." The main reason students said "no" was that this class, and the Terrascope program in general, creates a cohesive community and opening it up to others would remove this important aspect of the experience. Two other less frequently mentioned reasons were: students liked the smaller spring group (as opposed to the larger group that took the fall-semester class, which is open to non-Terrascopers) and any students who entered in the spring without the benefit of the fall class would lack the necessary background. Those who said "yes" thought it should be open to students who were in the fall class but were not members of Terrascope or, on principle, they thought the class should be open to anyone who was motivated and interested in the topic.

Multiple Regression Analysis

Although descriptive analyses are informative, it can also be valuable to conduct multiple regression analyses to understand empirically the factors that appear to be the most strongly associated with students' overall assessment of their experience. We aggregated variables by category to create indexes to use in carrying out a multiple regression analysis; the indexes were generated by summing the individual variables in various topic areas: the last month's teamwork experience; prototype development experience; final museum exhibit-development experience; teaching and learning experience; process and content learning; skill improvement; and overall assessment. (See Table 6 for more information on these indexes.) Chronbach's alpha reliability coefficients were computed to assess the internal consistency of each of these new measures. All the coefficients were over .70, an indication that these indexes were internally consistent and reliable.[1,2] In addition, three stand-alone questions were included in the regression analysis: perceptions of the class as a community, perceived future impact on the student's life of his or her increased knowledge of environmental issues, and satisfaction with the field trip. Table 6 gives details of variables that were included in the regression.

Table 6. Descriptive Statistics for Multiple Regression Analysis

Indexes and Variables	No. of Items	Response Range	Mean	Standard Deviation	Chronbach's Alpha
Overall Assessment Index	2	1-5	4.42	.68	.71
Teamwork Assessment Index: Last Month of Class (Student's ratings of the team experience during the last month of the term)	6	1-4	3.08	.73	.90
Prototype Development Index (Student's satisfaction with the prototype-development process)	3	1-5	3.71	.77	.84
Museum Exhibit-Development Index (Student's satisfaction with the final museum-exhibit development and exhibition)	3	1-5	4.27	.56	.74
Skill Improvement Index (Student's perception that his/her skills had improved; see Table 5 for a list of variables that make up this index)	4	1-5	3.60	.68	.78
Process and Content Learning Index (Student's perception that he/she had gained deeper understanding of content and/or processes; see Table 5 for a list of variables that make up this index)	5	1-5	4.00	.62	.73
Teaching and Learning Activities Index (Student's satisfaction with teaching and learning activities)	4	1-5	3.60	.72	.71
Perception that the class felt like a community	1	1-5	4.00	.91	
Satisfaction with the trip	1	1-5	4.83	.38	
Perception that increased understanding of environmental issues will influence student in future	1	1-5	4.20	.77	

A standard regression analysis was carried out to determine which factors seemed to be most important in predicting a student's degree of overall satisfaction with the class. A correlation matrix was generated to determine which variables were at least moderately correlated with the outcome variable and should, therefore, be included in the regression. A formula due to Tabachnick and Fidell[3] was used to eliminate some variables, since regressions with small samples should not have too many predictors.

After this culling, the regression included four possible predictors of a student's overall assessment of the class: the Final Month's Teamwork Index, the Process and Content Learning Index, the Final Museum Exhibit-Development Index, and the perceived future impact of the student's increased understanding of environmental issues. (Skill improvement was omitted because of its high correlation with the Process and Content Learning Index). Three predictors were statistically significant: process and content learning, the final museum exhibit-development experience, and the perceived importance of the student's increased environmental understanding. The results are displayed in Table 7, which presents the adjusted R square (which shows the joint effects of the predictors); the ANOVA F statistic (which assesses the overall significance of the model); the beta weight (measured in units of standard deviation and indicating how strongly each predictor influences the outcome variable if all other predictors are held constant); and the t test (which tests the null hypothesis that the variable explains none of the variance—i.e., that there is no linear relationship between this variable and the outcome variable). As Table 7 shows, the model is statistically significant and the adjusted R square is .44, indicating that forty-four percent of the variance in overall assessment can be explained by the joint effects of the four predictors. An adjusted R square of .44 is considered quite strong for a study measuring students' self-reported attitudes. The Process and Content Learning Index makes the strongest unique contribution to explaining the outcome variable, "Overall Assessment," when the variance explained by all the other predictors in the model is controlled. It has a beta weight of .33, indicating that a change of one standard deviation in knowledge improvement will result in a .33 standard deviation change in overall assessment. Of significant but secondary importance as influences on overall assessment are the perceived future impact of increased environmental understanding and the final museum exhibit-development experience. Perception of 1.016 as a community is not in itself statistically significant, but it does add to the adjusted R square (the percentage of the variance that the predictors explain).

Table 7. Multiple Regression Analysis Results
(Dependent Variable = Overall Assessment of class)

Predictors (Variables & Indexes)	Beta	t	Sig.
Process and Content Learning	.33	3.09	<.01
Perceived Future Impact of Increased Environmental Understanding	.23	2.23	<.05
Museum Exhibit-Development Experience	.22	2.27	<.05
Perception of 1.016 as a Community	.14	1.46	n.s.

Adjusted R Square = .44; F (4,72) = 15.714, p <.0001

Discussion

The assessment data provide a significant amount of information about students' experiences, which we shall discuss below. Before proceeding, however, it is important to bear in mind two caveats: First, these are self-reported results; that is, they reflect the students' own opinions, as collected at the end of the academic year. In some areas (e.g. overall satisfaction, whether the student would recommend the program to a friend, etc.) these are obviously reasonably reliable. In others, however (e.g. improvement in problem-solving skills or written communication skills), they are clearly somewhat subjective, and may under- or over-estimate actual gains. Fortunately, most of the data that concern us here, and that we shall discuss below, are closer to the former category than to the latter. The second caveat is that during the spring term students often mistakenly use "1.016" (that is, the subject number of the engineering/design component, which is offered in the spring) and "Terrascope" interchangeably. This means that sometimes when they are asked to assess characteristics of the spring-semester class they will instead offer an assessment of Terrascope as a whole. (This tendency is apparent, for example, in some of the open-ended comments quoted in "Overall Assessment," above.) We have done our best to minimize this effect, for example by constructing consecutive questions on the survey to ask for assessments of certain aspects of 1.016 alone and then the same aspects of Terrascope as a whole. That said, we shall now turn to a discussion of lessons we have learned, both from the assessment data above and from the process of conducting the program over the past several years.

It is clear that from the students' point of view the experience is a success, as shown by the percentage of students who report that they are "very satisfied" or "generally satisfied" (88 percent) and the number of students who report that they would "definitely" or "probably" recommend the program to a friend (94 percent). This point has also been made clear to us in other, more qualitative ways. For example, the most effective way to recruit new freshmen (or prospective freshmen) into Terrascope is to bring them into contact with former Terrascope students, whose enthusiasm for the program is palpable and contagious. The engineering/design component of the program is also successful at introducing and attracting students to engineering (95 percent report that they have gained an appreciation of the processes that go into design and engineering, and many students report that the experience has influenced them in the direction of majors or careers in engineering). In addition, the hands-on nature of the spring class is very popular among students, with many of them reporting in Developer's Journals that they are eager to turn to their Terrascope work because it makes for a change of pace from the problem sets and tests of their other classes. Such hands-on work is particularly effective for the surprisingly large number of students who now come to MIT with very little experience in tinkering, machine work or construction; Developer's Journals often describe students' experience of discovering the pleasure of hands-on work through Terrascope.

As assessment data in Table 7 show, these and similar aspects of the spring class—that is, the elements that make up the "Process and Content Learning index" (see Table 5 for details) are the best predictors of students' overall positive assessment. Students who have engaged fully in the experiential, project-based nature of the program are most likely to be happy in it. (Students' perceptions that their skills improved is also an important factor; it did not turn out to be a statistically significant predictor in the regression analysis only because of its high correlation with the process and content learning index.) The other factors we have identified that account for a significant component of students' satisfaction involve the program's environmental focus—students who feel that their new understanding of environmental issues will have an impact on their futures are more likely to feel positively about the experience—and, in the case of the spring semester, the unique experience of developing and building an interactive museum exhibit (see Table 7). On the other hand, students' perception of the class as a community was a relatively weak predictor of overall positive assessment. This is surprising, because in conversations, Developers' Journals and other forums students stress that the community feeling of the program is extremely important to them, and that it shapes their freshman year in a positive and significant way. We hope in the future to study this aspect of Terrascope more closely, in order to better understand this seemingly contradictory result.

Another surprise for us was the students' relatively low level of satisfaction with the Developer's Journals, with a small majority (54 percent) reporting that they are very satisfied or generally satisfied with this aspect of the class. For the instructors, the journals are a crucial element of the spring class. The students write very candidly, and so reading a week's set of journals gives us a very clear picture of what the students are experiencing, what their concerns are and what aspects of the class are working well or poorly for them. It is certainly the case that the journals benefit some students in ways they are not aware of—often, for example, we get information from journals that enables us to head off trouble brewing within a group, to alleviate a student's anxieties or to guide a team around some of the hidden pitfalls inherent in exhibit development.

Even so, the end-of-term surveys show that the journals are not as satisfying for students as they might be. We are using that information to improve the operation of the class, particularly in the area of instructors' comments on the journals. Each instructor reads and comments on each of the weekly journals, an extremely time-consuming but rewarding task. It is important, however, not only to respond but to respond in a timely way. Comments that come too late often miss the temporal window in which they could have a positive effect on a student or team. The sheer volume of journals makes it difficult to respond to each quickly, but we are working to improve our response time, in an effort to increase the usefulness to the students of this assignment.

Another lesson we have learned in the course of conducting the design/engineering class is that students want to start building something as soon as possible. We have therefore moved the prototype-construction project to much earlier in the semester than we had originally scheduled it (early to mid-March, instead of mid- to late April), and we are working to add some sort of construction or model-building at an even earlier phase of the class. (Earlier prototype construction and testing also makes it much more likely that students' designs will be significantly guided by the results.)

Conclusions

Perhaps the most consistent feedback we hear from Terrascope students about the program is that it has stretched them in ways they had previously not thought possible. One key to this has been the degree to which students themselves drive and lead the process. Another is the fact that at the end of each semester the students' work will be on public display and will be reviewed and critiqued by experts. When given control over their own learning, and simultaneously presented with such an end-of-semester challenge, the students engage deeply in the material and processes of the classes, and they drive themselves and their teammates to produce extremely high-quality work—often work of a sort they have previously never attempted. The combination of a fall semester in which students are launched directly into the team-building process, and a spring semester in which they exercise and cement their teamwork and project-management skills, leaves the students with great confidence in their ability to take on a complex task, break it into manageable parts, divide the work by specialty, and complete the project successfully. As a result, students who have gone through Terrascope often seek out and engage in other complex, team-oriented, multidisciplinary projects.

The fall and spring semesters complement one another in other ways as well. In particular, the research-based, detailed knowledge the students acquire in the fall semester gives them a strong foundation on which to base their spring work, and the organizational skills they acquire in completing the fall project put them in a good position to envision and complete the physical, design-oriented task of the spring. Conversely, the spring teamwork experience reinforces and cements the team-building skills students develop during the fall semester. The classes also complement one another in developing students' communication skills: all Terrascope classes stress, in their own ways, the importance of being able to communicate complex ideas to a variety of audiences, from the expert panelists who assess the fall semester's work to the community members and school classes that visit the spring exhibits to the broad audience that tunes in to Terrascope Radio.

The teamwork inherent in the students' Terrascope work, along with other aspects of the program (such as common work and lounge space, regular lunches, program-based advising, and the spring field trip), binds the students, teaching fellows, faculty and staff into a tight community, which for most students lasts well beyond the freshman year. And the program's environmental and Earth-system science focus has a deep and significant impact on the way many of the students envision their future careers and roles in society.

The program is still in development, and we continue to modify it based on the lessons we learn every year. We have already learned, for example, that the field trip is more important to the program than had originally been thought, both because it provides the students with a necessary reality check and because it fosters community spirit and collaboration. An issue that we are currently grappling with has to do with recruitment. As a freshman-year program, Terrascope is unable to benefit from peer-to-peer word-of-mouth recommendations: no matter how enthusiastic a student is about the program, he or she cannot influence other students in his or her year to join the program in the future, since that is not possible after freshman year. On the other hand, the program does benefit greatly from word-of-mouth between current or former students and prospective or entering freshmen; many Terrascopers report that they first became interested in the program when a current or former Terrascoper recommended it to them during Campus Preview Weekend, a spring event in which students who have been admitted to MIT are invited to stay on campus, observe classes, etc. We are currently working on other ways to let prospective students know what Terrascope has to offer them.

We also continue to explore the relationship between the two required classes, and to develop ways in which to link them more closely while retaining their individual characters. And, as the community of Terrascope alumni grows, we are working to assess and identify concrete ways in which the Terrascope experience's effects extend beyond the freshman year, affecting the Terrascopers' work both in their later undergraduate years and, eventually, in their careers beyond MIT.

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[i] This question was asked only in the '04 and '05 surveys. The respondent N = 56.
[ii] This question was asked only in the '04 and '05 surveys. The respondent N = 56.