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Building a Freshman-Year Foundation for Sustainability Studies: Terrascope, A Case Study

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Abstract

Terrascope is a freshman learning community at MIT, in which teams of students work to find solutions to large “unsolvable” problems and to communicate about those problems with a wide variety of audiences in multiple formats. The program strongly promotes students’ autonomy in focusing and structuring their work, and student projects culminate in public presentations, both to general audiences and to panels of technical specialists. Students who have gone through the program tend to show strong engagement with environmental and sustainability issues, as well as the skills and experience to work intensively on such issues within multidisciplinary teams. Here we present the program as a case study, with some discussion of factors that are key to its operation.

Introduction

Undergraduates who hope to make careers in sustainability science and related fields face an unusual challenge. They must find ways to acquire expertise in a variety of scientific and technical disciplines while at the same time learning how to appreciate the social, economic and political aspects of sustainability issues. They must learn how to work in multidisciplinary teams, drawing on the unique expertise of each team member while developing holistic approaches to the issues they face. Ideally, they should be able to exercise leadership within such teams, and to manage timelines, budgets, priority-setting and internal communication. Finally, they must learn to communicate their ideas and solutions to a wide variety of audiences, including not only their technical peers but also politicians, opinion leaders and the general public.

At the Massachusetts Institute of Technology, students can begin to develop these skills through a freshman learning community called Terrascope, an optional program in which roughly 5% of incoming freshmen participate in some form. The program includes academic and social components, and there are both formal and informal mechanisms through which upperclassmen, graduate students and alumni can continue to be actively engaged in the community after their own freshman experience. Terrascope is currently in its seventh year of operation (the program first accepted students for the 2002-03 academic year), and Terrascope students have shown strong records of engagement in sustainability issues throughout their undergraduate careers and beyond. In this article we present Terrascope as a case study, and we identify particular features and aspects of the program that have factored in its success.

Overall Structure

In Terrascope, students work in teams to find solutions to large, complex problems and to develop innovative ways to communicate with the general public about those problems. Throughout the program, students exercise a great amount of autonomy over the structure and focus of their work, and the program is driven and shaped largely by their enthusiasm and interest. The Terrascope program and its evolution over time are discussed in detail elsewhere (Epstein et al., 2006; Lipson et al. 2007); here we shall describe the program's key components.

The social organization of Terrascope is similar to those of other successful learning communities. Students have exclusive access to a classroom, lounge, computer cluster and kitchen, all of which are open to them 24 hours a day. The classroom can be used for small group meetings, meals, socializing and other functions, as well as lectures and classes. There are weekly lunches for the entire Terrascope community (students, alumni, faculty and staff), at which MIT faculty and staff discuss research in environmental and Earth-system science and engineering, as well as sustainability-related initiatives on the MIT campus. There are also local outings, dinners, movie nights and other social events throughout the year.

All freshmen participating in Terrascope are assigned academic advisors affiliated with the program. Typically five to 10 students will be assigned to a single "advising group," sharing a single advisor and one or two upperclassmen (usually Terrascope alumni), who serve as "associate advisors." Most advisors choose occasionally to meet with their advisees in this group setting, along with the usual individual meetings. The associate advisors may also meet with the advising group on their own. They do not perform any formal academic function, but as fellow-students who have recent experience both of Terrascope and of the ups and downs of the freshman year at MIT, they are a strong and valued source of information, guidance and support.

The full Terrascope academic program consists of a year-long sequence of two primary classes and two additional, optional classes. Terrascope students also enroll in the usual complement of MIT freshman classes, which they take along with their non-Terrascope peers. A field trip during Spring Break combines the academic and social aspects of the program and is a key part of the overall Terrascope experience.

The Academic Program

In the fall Terrascope class, Solving Complex Problems (offered by the Department of Earth, Atmospheric and Planetary Sciences, or EAPS), students are presented with a real-world problem that is highly complex in nature and that cannot be addressed by a purely scientific or technical solution. The class is informally known, and will be referred to here, as "Mission 20xx," where "20xx" represents the year in which the freshmen are expected to graduate; so, for example, during the 2008-9 academic year, the class is known as "Mission 2012." The central problem usually includes environmental or Earth-system elements. For example, in 2008-9 (Mission 2012) the problem is to devise a plan for providing a reliable supply of fresh water for western North America for the next century and beyond. In 2007-2008 the problem involved developing ways to preserve and steward the world's fisheries, and in 2006-7 the assignment was to determine how to address the problems of New Orleans in the wake of Hurricane Katrina, with the understanding that any solution had to be sustainable in the long term, not just for the next few decades. Certainly at some level students' knowledge of these issues will always be superficial, but the class is intended to teach them how to break down a problem, work together as a team, and integrate information from a wide diversity of sources. Whatever problem the students are faced with then serves as the theme for the entire Terrascope year. (Earlier Terrascope theme problems are described in detail by Epstein et al. (2006).)

During the first Mission class, the students are told that they have one semester, as a group, to come up with a solution to the year's theme problem. Their solution is to be communicated via a comprehensive website, which they must develop and which will be on-line for a minimum of five years. In early December they present and defend their solution in front of a panel of experts brought to MIT for the occasion, as well as MIT students and faculty and other interested people. The presentation is webcast live and is then archived for future viewing.

To help students begin to attack the problem, the primary instructor of Mission 20xx[*] suggests five to 10 general topic areas for which teams might take responsibility, and students then self-organize into individual teams. In keeping with the high degree of student autonomy that is characteristic of Terrascope, these teams are highly flexible. Students may decide at any time to combine or reconstitute teams, or to change any team's focus area.

At this point it becomes the students' responsibility to take ownership of the problem and the process through which they will address it. Over the course of the semester they decide, collectively, which parts of the problem to tackle in detail and how to coordinate their work into a coherent whole. They also decide, within teams and as a group, how best to make use of the intellectual resources with which they are provided. There are four primary sources for these intellectual resources: librarians, upperclass students, alumni mentors, and specialist instructors. Each team is assigned an MIT librarian with expertise in the team's focus area and one or two "Undergraduate Teaching Fellows" (UTFs). The UTFs, who are upperclassmen who have been through Terrascope, serve as facilitators and advisors but not as instructors. In addition, the teams, as well as the class as a whole, are put in contact with Alumni Mentors, who bring expertise either in the specific problem with which the students are dealing or in organizational and problem-solving strategies. The Alumni Mentors attend class, meet with the students, or communicate via email with teams and team members. As necessary, specialized instruction is provided in specific areas, such as Global Information Systems (GIS) and webpage construction. In most cases, we have found that the students know very little about the problem at the start of the semester and that getting them started doing meaningful research is one of our greatest challenges. Despite the general perception that first-year students should know how to do research, synthesize scientific papers and discuss their findings, our experience is that these skills need much development over the course of the semester.

By the time of their final presentation the students have adopted the problem as their own, and they are often very passionate about the solutions they propose. They have had a chance to experience the tradeoffs that are inevitable in all such problems, and they know from first-hand experience that, unlike the tests and problem-sets they deal with in other classes, real-world environmental issues have no “right’ or “perfect” solution, but rather an array of possible solutions, each of which comes with its own advantages and disadvantages. They have acquired knowledge in a wide variety of areas, and they are able to speak with confidence about the issues in front of a distinguished panel of experts.

Examples of previous years’ solution websites can be found at: http://web.mit.edu/12.000/www/m2011/finalwebsite/ and http://web.mit.edu/12.000/www/m2010/finalwebsite/ . Webcasts of the corresponding panel presentations are at: http://web.mit.edu/webcast/mission2011/mit-mission2011-32-123-04dec2007-220k.ram and http://web.mit.edu/webcast/mission2010/mit-mission2010-32-123-05dec2006-220k.ram

Beyond the specific problem on which they have focused, the students have also had the chance to work as part of a team. Overall the teamwork experiences are very positive, but the students also have experiences in which their team did not function as well as it might have. Some students report deeply frustrating experiences. The level of commitment to the class is variable and to some extent a small nucleus (3-8) of students assume a leadership role about three quarters of the way through the semester. There is little shyness involved when calling out members of the class who have not participated as much as others. This sort of peer pressure is quite effective at motivating those who have not been as deeply involved. Most students feel that they learn important lessons from the experience, and they are able to carry their new understanding of what makes teamwork successful or unsuccessful into the next team project they work on. The two-semester nature of the Terrascope academic program gives them that chance immediately: in the second semester they will again work in teams, cementing and further improving the teamwork skills they have developed in the first semester.

The core second-semester Terrascope class, offered by the Department of Civil and Environmental Engineering (CEE), is called “Communicating Complex Environmental Issues: Designing and Building Interactive Museum Exhibits.” As in the first semester, students work in teams and exercise a great deal of autonomy and control over their project. In the second semester, however, the nature of their work changes in two ways: (1) They design and build functioning physical apparatus, and (2) Their primary audience is now the general public. Thus the two Terrascope classes, taken together, present the students with a wide array of challenges, intellectual and physical, and give them the opportunity to practice multiple modes of communication.

In the spring class, that communication takes the form of interactive museum exhibitry. The students are assigned to new teams, and each team is responsible for developing, designing and creating its own interactive and/or immersive museum exhibit.[++] The exhibit must be on a topic related to the year's theme problem, but teams are free to select and alter their topics as they choose. Teams may coordinate with one another, but they are not required to do so (other than to come up with a floor plan that includes each team's exhibit). The exhibits are constructed in a public, high-traffic space at MIT and opened for several weeks to the MIT community and the general public. They are evaluated by local high-school students (representing a general audience) and by a panel of museum professionals (who can assess the finer details of exhibit design and construction).

As in the fall semester, teams in the spring class are assigned UTFs, who work as facilitators and who are also available to help the teams during final construction. Also as in the fall, each team is assigned its own librarian, to help with research and sourcing of exhibit content. For highly technical exhibit-related questions (e.g. where to find certain kinds of materials or electronic components), students are referred to staff members of local museums.

The spring class takes students through a full design/build engineering process. Teams begin with concept development and brainstorming, leading up to a preliminary exhibit proposal. Based on that proposal, they create prototypes of some of their exhibit elements; the prototypes are tested by groups of local high-school students, and the Terrascope students use information from that prototyping session to develop a final exhibit proposal, including a timeline and a budget. For the rest of the semester the teams focus on building and testing the exhibits, redesigning as necessary.

Every week during the semester, each student writes a short (1-2 pp.) "Developer's Journal" entry, reflecting on his or her team's work and progress that week. This structured reflection helps students see the larger picture even during an intense building process. In the process of writing the journals, many students develop new insights into the team-building and teamwork processes, and writing about those insights helps solidify them in the students' minds. In addition, the journals give instructors a close look into the functioning of each team, and a strong sense of each student's level of effort and participation.

The exhibits are usually extensive, combining interactive devices and immersive experiences. In most years, some exhibit elements have been adopted by museums and other institutions in the Greater Boston area and elsewhere for use as stand-alone elements or as prototypes for more sophisticated exhibits. A virtual tour of one year's exhibits can be found at: http://web.mit.edu/srudolph/www/2007-2008/Terrascope/Exhibits/index.html#top .

[++] Interactive exhibits are those in which visitors interact with some component or components of the exhibit; ideally that interaction goes beyond simple button-pushing or flap-lifting, but those are acceptable and sometimes effective modes of interaction. Immersive exhibits are those in which the visitor feels immersed in an environment, such as an underwater scene or a simulation of a hurricane-damaged house.

In addition to the core classes, there are two optional Terrascope classes. One of these, conducted during MIT's January Independent Activities Period, is designed to prepare students for the spring class by helping them understand how people learn in museums and what makes for an effective exhibit experience. The class meets for one week, 5-6 hours a day. Each day the class travels to a different museum in the area. There students meet with staff to discuss the museum's exhibit-development philosophy and approach, and then they explore the exhibit floor to observe first-hand how visitors interact with exhibits. Afterward there is a debriefing session with museum staff, during which the students reflect on what they have observed and staff discuss the specifics of the exhibits the students visited. Every day also includes brainstorming sessions, during which the students identify aspects of the year's theme problem that might be communicated well by museum exhibits and develop preliminary ideas about what each exhibit might contain. The output from these brainstorming sessions serves as the springboard for the core Terrascope class's work during the spring semester.

The other optional class, Terrascope Radio[+++], is a spring-semester class in which student teams create radio programming about the year's theme topic, broadening their communication skills to include yet another medium and audience. The class is designed to meet part of MIT's Communication Intensive requirement, and students take it concurrently with the primary Terrascope spring-semester class. Because most students will not have had much (or any) experience listening to radio in an analytic way, much of class time is spent on critical listening to, and analysis of, a wide variety of radio pieces. Students work to understand what makes these pieces effective, how the producers have incorporated various elements and narrative techniques, and how, in general, radio producers use the various tools available to them to create dynamic, interesting, engaging and informative radio.

Concurrently, the students are learning the technical details of radio production and creating their own radio pieces, putting into practice their new knowledge of how effective radio programming is produced. They are issued professional-quality, portable sound-recording equipment and audio-editing software, and through a series of short assignments they learn how to gather sound, select and arrange clips, write and voice scripts, and finally mix their sound to create a coherent piece. Then they work in teams to plan and develop their final project, a 15-20 minute production about some aspect or aspects of the year's Terrascope topic. Finished pieces are broadcast on WMBR, the MIT radio station, and are then made available for licensing to other stations through the Public Radio Exchange. Terrascope Radio student productions have been licensed and played by public and community radio stations throughout the U.S., reaching a broad and diverse audience. To hear samples of some student productions, go to: http://web.mit.edu/terrascope/www/radio_archive.html .

The final key component of the Terrascope program is the Spring Break field experience, during which students, UTFs, faculty and some staff travel to a place that is central to the year's Terrascope theme. Trips generally involve visits to important sites, lectures by

[+++] Created in collaboration with the MIT Program in Comparative Media Studies and taught by AWE.

local experts, meetings with political authorities and a certain amount of field exploration. One of the most important aspects of the trip is that it gives students the chance to experience the reality of a place they have been studying from a distance all year. When they do so, they often come to realize that there are complexities and human elements that were not taken sufficiently into account in the proposed solution that they developed in the fall semester. This is an extremely important experience, because it makes it clear to the students that no amount of abstract study can substitute for really understanding the area and the people whose problems one is hoping to solve.

In addition, students use the trip as an opportunity to gather artifacts and photographs, and to refine the plans for the exhibits that they are producing during the spring semester. The trip falls between the prototyping period and the due date for teams' final exhibit proposals. Thus, the timing is right for students to incorporate any new knowledge or understanding that they have gained during the trip into their work. Terrascope Radio students use the trip as an opportunity to gather sound, conduct interviews, and develop themes for their final program.

The trip is also invaluable from a social point of view: it serves as a major bonding experience for the Terrascope community, not only for the current freshman class and faculty, but also for the Terrascope students from previous years who are serving as UTFs and Teaching Assistants. In end-of-year assessments, students consistently point to the trip as a unifying experience that shaped the rest of their Terrascope year.

Assessment

In addition to the usual class evaluations, we conduct annual, in-depth end-of-year assessments (primarily via online surveys), as well as mid-year assessments in selected years. These have provided a wealth of data on students' experiences, their perceived gains in skill, confidence and knowledge, and ways in which the program could be improved year-to-year. Results from the first three years of the program are reported by Epstein et al. (2006) and Lipson et al. (2007). Here we present a portion of the data gathered throughout the six years of the program that have been completed as of this writing, with a focus on results that are directly relevant to sustainability education. A more comprehensive report on data from the program's first six years will be presented in a future publication. Data presented here refer specifically to students' spring-semester experiences. Of the 186 students who completed the spring-semester class over the six years discussed here, 70% (130 students) responded.

As Table 1 indicates, students viewed the hands-on nature of the Terrascope experience to be extremely positive, and they felt that the strong emphasis on communication—on using one's own new knowledge as a basis for teaching others—contributed deeply to their own learning. They also felt strongly that the experience had helped them to improve their teamwork and problem-solving skills, both of which will be crucial to their future ability to work in the interdisciplinary teams so often required to address problems in areas having to do with sustainability. Beyond these improved skill-sets—which are a primary objective of the Terrascope program—two-thirds of students felt that they had also gained specific knowledge and appreciation of particular environmental problems and the scientific, economic and political issues that underlie them.

Perhaps most encouragingly, a very high percentage of students (83%) felt that the deeper understanding they had gained of environmental issues would influence them in the future, regardless of their choice of career or major. As incoming freshmen, Terrascope students begin the program without a declared academic major. When they do choose their major fields (near the end of freshman year), they tend to distribute themselves among the various schools and departments of MIT in roughly the same proportion as other freshmen (with a slight bias in favor of EAPS and CEE). This means that through Terrascope, students who report a potentially life-changing new appreciation of environmental issues are distributed in majors that are not traditionally associated with environmental sustainability. Since sustainability studies actually require expertise from nearly every scientific and technical discipline, it is important to have a pool of specialists throughout the science and engineering specialties who have an inclination to use their expertise in environmentally-related projects.

Beyond Freshman Year

Students who have been through Terrascope tend, as upperclassmen, to retain their interest in working on issues having to do with sustainability and the environment. Many of them gravitate towards projects involving complex environmental issues, and they often take leadership positions in groups or organizations devoted to such issues. A number of Terrascope students' post-Terrascope projects are described by Epstein et al. (2007). Here we briefly outline a few examples.

In 2006, two Terrascope students formed the Vehicle Design Summit (VDS), an organization that promotes radical innovation in sustainable modes of automotive transportation (http://www.vehicledesignsummit.org/website/). During its first summer, VDS brought 55 engineering students from 21 universities in 13 countries together at MIT for eight weeks in order to create prototypes for energy-efficient cars that relied on a variety of energy sources. Working in teams, the participants designed and built four working concept cars by the end of the summer. The organizers then focused the project outward, distributing it among teams based at roughly 20 universities worldwide, with the goal of creating highly efficient vehicles, whose designs would be "open-source" and so available to any interested manufacturers around the globe. In addition to the technical issues faced by VDS, the organizers have had to coordinate the work of multiple teams while protecting each team's autonomy; they have had to deal with the logistics of bringing participants together, housing them and finding work space and materials; and they have had to secure the funds necessary for the project (of which they have raised roughly $500,000 to date). This effort has required many of the skills and attitudes that Terrascope hopes to foster: willingness to take on large-scale, complex problems involving sustainability; ability to bring together and manage teams of accomplished individuals with diverse skills; attention to all the details of a problem, not just the scientific and technical issues; and an inclination to look to innovative solutions for global problems.

Another Terrascope student, motivated by the devastating earthquake that struck her native Pakistan in 2005, was inspired to develop earthquake-tolerant housing appropriate for the large segment of the population that lives in remote mountain villages in the seismically-active region. She noted that the building plans promulgated by major non-governmental organizations (NGOs) were unsuitable both because they called for materials (e.g. reinforced concrete) that would be difficult for villagers to obtain and transport, and because the designs themselves were not sensitive to local culture, taste and habits. With assistance from Terrascope and the MIT Undergraduate Research Opportunities (UROP) program, she developed a series of designs that relied largely on local or locally-obtainable materials and that met villagers' practical and aesthetic standards. As her project progressed, she decided that the most good could be done in the short term by designing school buildings, since many earthquake-related deaths occur in schools. She is currently working with several major NGOs in the area to create demonstration buildings based on her designs.

Many Terrascope students undertake projects closely related to the specific topics on which they have worked during their Terrascope year. For example, Terrascope students from the 2007-8 academic year wanted to continue working on global fishery-related problems after their academic work in Mission 2011 had ended. As a basis for future work, they have recently created a new campus organization, the MIT Society for Ocean Conservation, which will focus on educational and political, as well as scientific and technical, approaches to fishery-related issues. Another group of students, whose work in Terrascope Radio led them to want to continue using radio programming as a means of communicating environmental information, have created their own radio program, Terravoice, which focuses on a variety of environmental topics and is broadcast weekly on WMBR. Other projects undertaken by upperclassmen who have participated in Terrascope (often working in groups with other, non-Terrascope students) include: Biodiesel@MIT, an organization that will process used vegetable oil from campus eateries into biodiesel fuel to be used in MIT vehicles; the MIT Museum Boat, a group of students working to create a science museum on a boat, which could be effectively shared by Caribbean islands having populations too small to support full-time science museums; and an in-depth analysis of MIT's recycling system, paying particular attention to the incentives and constraints affecting the custodians responsible for collecting, organizing and transporting materials to be recycled.

Discussion

Students emerge from Terrascope inspired to work on sustainability issues, both local and global, and equipped with the intellectual and organizational skills to begin that work. They also exhibit strong loyalty to the program and enthusiasm about continuing to participate actively in the Terrascope community, either formally (e.g. by working as

UTFs or on Terrascope-based UROP projects) or informally. We believe that a number of factors have contributed to the program's success. Key among these are:

- Work done in Terrascope is driven largely by the students' own interest and enthusiasm, with students making the primary decisions about how to focus and structure their work, the areas on which they will concentrate, timeline, distribution of labor, etc. Thus the students are actively engaged in the work from beginning to end and they feel a strong sense of ownership. This is pedagogically risky, and instructors fully understand that each year will be different in terms of the students' ultimate success.
- Terrascope classes culminate in public presentations or other events (globally-webcast panel presentations, exhibit openings and radio broadcasts) at the end of each semester. These are "high stakes" events, in the sense that much of the semester's work rides on the outcome of each event. The students' primary motivation is to make these presentations something they can be proud of, rather than to earn a grade. We have found that this is by far a more effective source of motivation than academic distinction could provide.
- Upperclassmen and alumni continue to participate in both the academic and the social components of the program, providing freshmen with role models and mentors, and giving the program continuity from year to year.
- All aspects of the program are strongly shaped by students' input and advice, giving them a strong sense of belonging that continues through and beyond their time at MIT.
- Students' work has the possibility to live on and continue to have an impact, e.g. through archived Mission web pages and presentations (which continue to draw active interest from outside MIT for years after their creation); through exhibit components that are adopted by major museums; and through radio programming that is licensed for broadcast nationwide. This gives students the understanding that their work is more than an academic exercise, and that it can have a real impact.
- The community setting provides strong extra motivation to work together effectively and encourages students to commit themselves to the program, both in their freshman year and beyond.

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Tables

Table 1. Terrascope Students' Self-Reported Learning Gains (Spring Semester)

	Agree/ Strongly Agree (collapsed categories)	Mean (5-pt. scale)	SD (5-pt. scale)
Process/Content Learning			
Learned from the hands-on experience	92%	4.4	.72
Experience of teaching others helped me learn material more thoughtfully and deeply.	74%	3.9	.88
Gained greater appreciation of global environmental problems and the science behind them.	68%	3.9	.99
Gained knowledge about scientific, economic, and political issues	67%	3.8	1.0
Skill Improvement			
Improved teamwork skills	84%	4.2	.86
Improved problem-solving skills	80%	4.1	.84
Personal Development			
[My] increased understanding of environmental issues will likely influence me in the future (no matter what major or career I choose).	83%	4.2	0.83