Environmental Sustainability Through GIS: An Online E-Seminar for Higher Education

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Abstract: *This article discusses the development of an online e-seminar that uses a geographic information system as the basis for its major activities. Students of the seminar explore the concept of environmental sustainability in a conference-style format with the perspectives of nine Columbia University faculty members affiliated with the Center for International Earth Science Information Network. Students experience innovative presentations from each faculty member, participate in online forums, and complete online activities using a customized mapping tool with data from the Environmental Sustainability Index. The activities are designed to engage the student as an active participant in exploring environmental sustainability.*

Introduction

Typical online courses present content in a linear fashion, essentially replicating what a student would receive in a lecture-based face-to-face environment. Students are generally directed to move from module to module in these courses in a strict journey from simple to more complex concepts. This is especially typical in the science curriculum, where the common conception is that one cannot explore sophisticated issues without the proper foundation. In addition, as David Perkins pointed out, science (among other subjects) has evolved a "trivial pursuit" educational philosophy, where the accumulation of facts across a breadth of topics has become an accepted principle of a good education (Perkins 1992). This article discusses an innovative approach to online science education that challenges these common techniques and assumptions through its non-linear hub-and-spokes design and the use of a research-level dataset embedded in a GIS environment.

The general concept of "environmental sustainability" refers to the necessary balance between human wants and needs and the capacity of the natural systems of the earth. A more specific definition is elusive as the perspectives of diverse disciplines (i.e., oceanography, architecture, public health, and economics) all contribute to the concept and have their own spin on the underlying principles needed to construct a more complete definition.

For those interested in exploring the crucial issues related to preserving and maintaining the global environment, the Center for New Media Teaching and Learning (CCNMTL, http://ccnmtl.columbia.edu) in collaboration with the Center for International Earth Science Information Network (CIESIN, http://www.ciesin.columbia.edu) created a conference-style e-seminar (Figure 1) that allows students to participate in nine online modules on environmental sustainability from varying perspectives. As a means for connecting these perspectives, participants perform a series of related activities using a geographic information system (GIS) tool based on a dataset known as the Environmental Sustainability Index (ESI) and communicate with each other using an online asynchronous bulletin board forum.

The ESI was created through a partnership of the World Economic Forum, the Yale Center for Environmental Law and Policy, and CIESIN as a tool for scientific researchers in multiple disciplines. The index is an effort to illuminate the specific components that are crucial to environmental sustainability, and, at the same time, to integrate disparate elements into a synoptic view of sustainability around the world. It does so by combining a wide range of social and environmental measurements in a hierarchical structure, creating layers of data that provide an increasingly general view of broad issues of environmental sustainability. The ESI dataset is used in this e-seminar as the data behind a global GIS Map Viewer used for a variety of activities in each learning module. The structure of the ESI dataset is discussed later in this article.

This e-seminar was completed as part of two larger Columbia University initiatives. One initiative, led by CCNMTL, is dedicated to improving the purposeful use of new media in higher education. The second initiative is led by Digital Knowledge Ventures, the administers of Columbia Interactive (http:

Figure 1. The launch screen for the e-seminar.

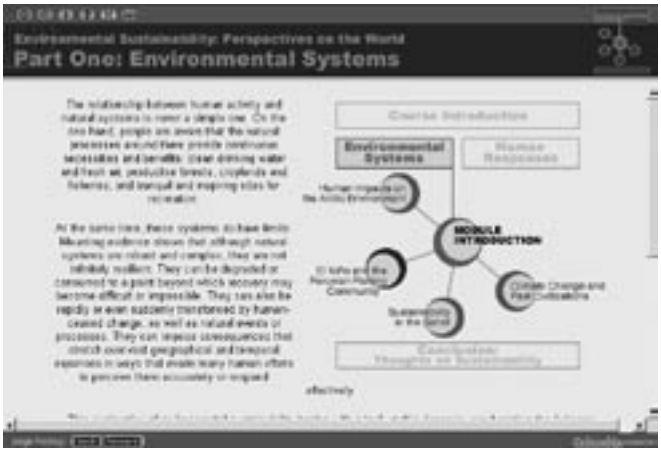

Figure 2. Introduction to Part One, which focuses on Environmental Systems. Note the hub-and-spokes scheme with four nodes representing the modules in this section.

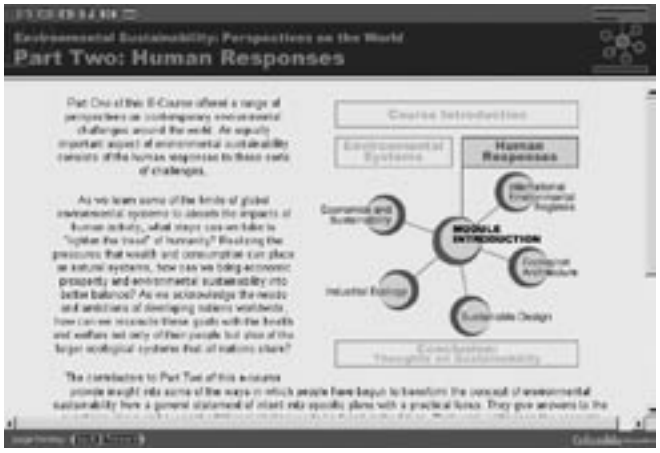

Figure 3. Introduction to Part Two, which focuses on Human Responses. Note the hub-and-spokes scheme with five nodes representing the modules in this section.

//ci.columbia.edu), and the purpose is to extend the intellectual resources of the University to the world and bring the collaborative energy of a worldwide audience to Columbia University through the creation and support of digital exchanges of knowledge, information, and ideas.

E-Seminar Description and Design

Environmental Sustainability: Perspectives on the World is an online e-seminar designed for adult participants (typically university students or university-educated people) interested in a science-based non-credit learning experience (Environmental Sustainability: Perspectives on the World is available to anyone for a small fee at http://ci.columbia.edu and at http://www.fathom.com). The seminar is set up with nine modules from different disciplines that can be experienced in any order. To provide a general framework, there are two groups, "Part One: Environmental Systems," which contains four modules that focus on monitoring the interaction between natural environments and human actions, and "Part Two: Human Responses," which contains five modules focusing on action plans for fostering sustainable development. As seen

Figure 4. A view of the module by Kenny Broad on El Niño and the Peruvian Fishing Community.

in Figures 2 and 3, each group or part is designed as a hub-and-spokes set, with the hub acting as the introduction and the nodes on the end of each spoke as the individual modules that can be completed in any order.

A different Columbia-affiliated faculty member or researcher leads each of the nine modules, and each contributor is from a different discipline. Each module contains a sample of the contributor's major research interest, video interviews with the contributor on relevant topics, and activities using the ESI Map Viewer tool.

In Dr. Kenny Broad's module (Figure 4), students view a discussion of his observations of El Niño's effects on Peruvian fishing communities. Then they perform activities related to Peru using the ESI dataset in the Map Viewer to further explore the ideas and relate them to the other modules.

Because students can work through the modules in any sequence, a set of five overarching questions were designed for consideration throughout the experience:

- How would you define "environmental sustainability"? How does your definition compare to others?
- Which environmental systems do you feel are most important within the general framework of environmental sustainability? How do you think those systems are faring today?
- What are the critical steps that people should be taking toward environmental sustainability?
- What are the lessons evident in environmental data? Do you think datasets such as the ESI represent environmental challenges, or would you recommend another approach?
- What is your perception of environmental sustainability, both as a general principle, and as a practical strategy? Do you feel it is succeeding or failing, and why?

These questions are written generally such that students can generate answers after completing any number of modules in the public online asynchronous forum attached to the course. The intention is that they will revisit their answers and reply to other students' comments as they proceed through more expert

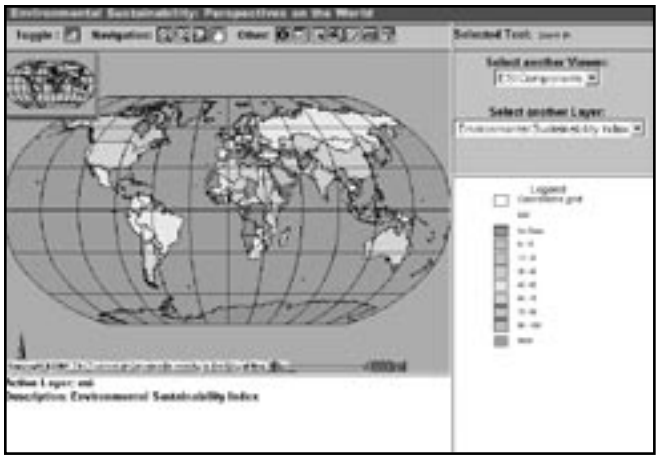

Figure 5. A view of the top level of the ESI Map Viewer.

perspectives and activities. This approach is an attempt to model scientific thinking in a cyclical structure of positing theories, exploring data and experimenting, revising one's theories, and defending one's ideas.

ESI Map Viewer and Assignments

When students begin an activity in the ESI Map Viewer (the ESI Map Viewer was developed in ArcGIS and served using ArcIMS), they see a global map and a color key showing the rankings of all the countries in the ESI (Figure 5). Students are then directed to select particular data layers that show more specific details relevant to the activity. For Dr. Broad's section, students focus in on South America (Figure 6) to compare the sustainable conditions in countries neighboring Peru.

When examining a particular region, students can use the zoom feature to see more detail on particular regions of the world and examine data tables displaying the scores for selected countries. Students can also access visual representations of the ESI rankings for a group of countries (Figure 7). These graphs are especially helpful when trying to distinguish between countries with similar overall rankings that may have very different means for achieving their rank. For example, one might note in Figure 7 how Bolivia and Chile have nearly identical ESI rankings (#30 and #31, respectively), but their strengths and weaknesses are clearly different as evidenced by Bolivia's very low "Reducing Human Vulnerability" score versus Chile's relatively balanced scores across all components. Students examining this issue might then explore the indicators and variables in the various components to see what contributed to these countries' differences, whereas if they relied only on the overall scores, students might assume these neighbors operate very similarly.

One method for exploring indicators and variables is to use the Query feature for analyzing the ESI dataset (Figure 8). This search tool allows students to select a particular variable and set up a search query string, which when executed will look through the ESI dataset for matches and present the results in a data table.

Figure 6. A zoomed in view of South America in the ESI Map Viewer. Note the data for Argentina shown along the bottom.

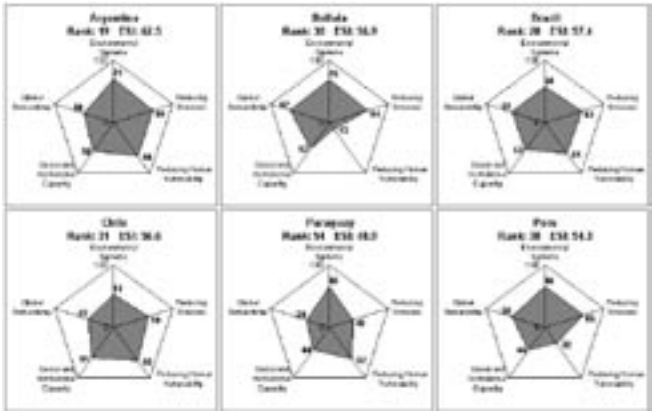

Figure 7. Radargraphs of six South American countries showing their ESI overall rank and score as well as a breakdown into the five major components of the ESI.

Figure 8. The search query interface.

In Dr. Broad's module, for example, students are encouraged to perform searches on the governmental and social aspects of human activity that contribute to environmental sustainability and compare Peru with other countries' scores in these areas. Two variables of particular interest in this case are "Stringency and Consistency of Environmental Regulations," a value determined through a survey published in The Global Competitiveness Report by Oxford University Press and "Reducing Corruption," a standard value of government corruption published by the World Bank. Using the search tool, students can look for a correlation between these variables in an effort to explain how bureaucratic systems impact the environment.

ESI Data Structure

As illustrated in Figure 9, the ESI begins with data at the Variable level with over 60 separate measurements drawn from a wide range of data sources worldwide. These Variables include many different types of data, such as chemical measurements of air and water pollution, assessments in areas such as biodiversity water scarcity created by university research institutes, international non-profit

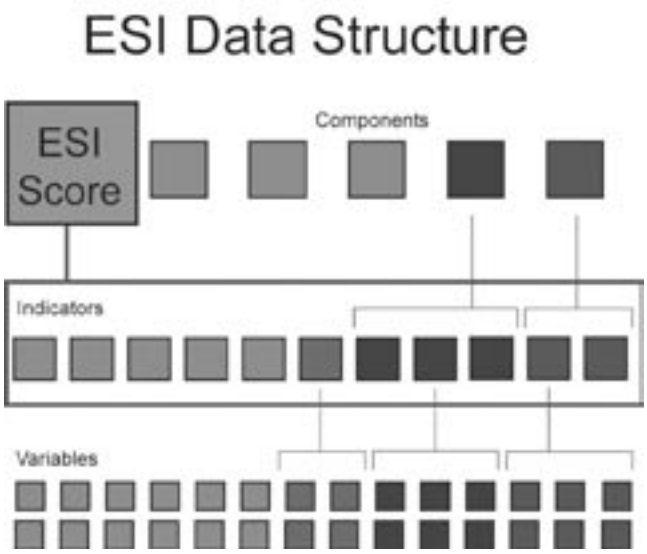

Figure 9. Data structure of the ESI.

organizations, and survey responses from governmental officials regarding the state of legal and social systems.

The Variables are then grouped and combined to create 22 Indicators, which give a more general overview of a single topic relevant to environmental sustainability. Examples of Indicators include the overall level of air quality within a nation's borders, the responsiveness of national businesses to environmental concerns, and the vulnerability of local populations to health effects from environmental conditions.

These Indicators are subsequently combined in two ways: One method groups them into five broad categories, called Components, which reflect a nation's overall environmental sustainability in the areas of Environmental Systems, Reducing Environmental Stresses, Reducing Human Vulnerability, Social and Institutional Capacity, and Global Stewardship.

The second method combines all 22 Indicators into a single number—the overall ESI Score—a ranking of the world's nations on a scale of 0 to 100 (the higher the better) in terms of their environmental sustainability. Thus, the ESI proceeds from the most specific, quantifiable expressions of a range of factors crucial to environmental sustainability towards a single, comparable standard that allows comparison of most of the world's nations.

Implementation

To date, more than 65 users have signed up for Environmental Sustainability through Columbia Interactive, ranking it the 12th most popular e-seminar on that e-learning portal (available for a small fee at http://ci.columbia.edu and at http://www.fathom.com).

It has been difficult to measure the effectiveness of the site, as there has been almost no contact between users and the maintainers of the e-seminar. The fact that there have been almost no technical problems reported is a good sign of quality technical development, but there has been almost no use of the course forum, which indicates either students are comfortable operating independently or that they are struggling with the complexity of the content to the point that they do not feel comfortable sharing their thoughts.

We will continue to monitor use patterns in the coming months to determine whether redesign of the course is necessary to try to increase communication between participants. However, a more thorough evaluation of the effectiveness of this e-seminar is warranted. As a start, an evaluation could attempt to validate many of the design and curriculum choices that were made in an effort to answer these questions with student participants:

In what way can students of the e-seminar…

- articulate their own definition of environmental sustainability and evaluate other people's definitions?
- discuss environmental systems and human responses examples provided by each faculty member intelligently?
- build a case for and against the use of datasets such as the ESI?

Answers to these questions and others would undoubtedly point us toward a host of issues that we could take on in future redevelopment.

Discussion of GIS Tools in Education

CCNMTL and CIESIN are currently developing several more educational environments, with GIS tools playing a key role in the teaching and learning process. One new project, known as Poles Together, is a face-to-face seminar that leads students through the journeys of polar explorers and related datasets through the use of online polar projection map viewers. Columbia University's Urban Planning department has an Urban Design Studio that is also collaborating with us in the development of an online study environment for collecting and sharing information around hazard mitigation in particularly vulnerable cities. A student group recently completed an project on Istanbul where students were charged with identifying earthquake prevention and response measures. For this project, student-collected data were loaded into map viewers and shared between New York City and Istanbul.

In all of these projects, CCNMTL is concerned with the educational effectiveness of GIS teaching and learning environments. To that end, it is important that GIS tools evolve communications and multi-user features that foster better student-to-student collaboration as well as faculty-to-student communication. Numerous studies point out that augmenting constructivist learning environments with communications tools benefits students in many ways. As one example, a study by Daniel Edelson et al. (1996) points out that while "(c)onstructivist learning environments have made great strides in moving away from the knowledge transmission model of learning toward an active learner model…active learning can be further enhanced through social interaction." For the environmental sustainability e-seminar, CCNMTL relied on an external course forum system that has not been effective in this course to date. Alternatively, if students could annotate actual data in the GIS tool or post comments in a bulletin board system that was linked to particular data objects

or layers in the GIS environment, courses could be designed with more specific collaboration assignments that would foster more focused tool use and would result in better student engagement with the content. Instructors could see more direct evidence of student work and make comments of their own to guide them further while they are still immersed in the GIS environment. As it stands now, most instructors have to treat GIS tools as "black boxes," which limits their ability to gauge student progress and engagement with the environment.

Still, one cannot deny the current power of GIS to bring research-level datasets to the educational community. Providing online access to sophisticated mapping tools that can be implemented quickly into curriculum is a large step that should not be taken lightly. Our hope is that developers of GIS authoring tools will consider the needs of the educational community in future versions of its products. If done well, one can imagine enormous benefits for students in all disciplines, who will gain critical spatial data analytic and problem-solving skills and may very well come to rely on GIS in their career pursuits, whatever that chosen profession may be.

The process of designing and developing this e-seminar has shown us that there are great possibilities for innovative online GIS-based educational environments, but there are many more questions than answers about the most effective way to design and implement them. Our goal with this project was to create a unique online approach for participants to learn environmental sustainability concepts through focusing students on experiencing multiple perspectives and performing activities with an authentic dataset. Our next challenge is to examine the student-faculty experience in this e-seminar and our other GIS projects in order to be able to more confidently assert the benefits for faculty and students to develop and use these environments in their teaching and learning.

About the Authors

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