WebQuests as an Integrative Experience in Introductory Environmental Engineering

Mary Cardenas
Harvey Mudd College
Claremont, California

Abstract

An Integrative Experience was developed as part of an introductory environmental engineering course at Harvey Mudd College. The Integrative Experience was developed to help the college students consider the relationship of science and technology with contemporary society. Junior and senior students enrolled in the course designed WebQuests for middle school students. The WebQuests involved the integration of an environmental issue, problem, or technology and societal effects. WebQuests were designed for a middle school audience in order to expand the amount of engineering outreach that is done at the K-12 level. The HMC students chose WebQuests topics including nuclear and alternative energy; the Los Angeles aqueduct; farming practices and conservation; a cyanide spill in Romania; deforestation; air pollution; and energy conservation and planning. The WebQuests were tested by middle school students in Fontana, California to determine their usefulness in introducing engineering to middle-school students, and feedback was received.

I. Introduction

Harvey Mudd College students are required to take an Integrative Experience (IE) in order to satisfy graduation requirements. Harvey Mudd College is an ABET-accredited liberal arts college of engineering and science, and the engineering program at Harvey Mudd College is a general program. An IE is defined by the curriculum committee at HMC as a course that includes consideration of one or more issues involving the relationship of science or technology with contemporary society.

ABET criteria state that engineering programs in the United States must demonstrate that their graduates have the broad education necessary to understand the impact of engineering solutions in a global/societal context, and knowledge of contemporary issues[1]. Some institutions have been satisfying science, technology and society (STS) education by offering separate, specific courses. These courses include sophomore- and junior-level STS courses[2-3] where the students study the historical development of technology and society, and write reports and essays on STS topics. At the Colorado School of Mines, the students in the Guy T. McBride, Jr. Honors Program in Public Affairs for Engineers take seven semesters of interdisciplinary seminars examining society and technology[4]. At Arizona State University, Guilbeau and Pizzicani developed a bioengineering course to satisfy the ABET criteria on society and technology[5]. At ASU, case studies, creative controversy, group position papers and oral debate were used to study bioengineering as it relates to society.

In order to satisfy Harvey Mudd College's IE and ABET requirements, we decided to modify an existing environmental engineering course instead of developing an entirely new course. A previous study of societal issues in engineering education measured references to context and their influence on subject matter for courses in basic and applied sciences and engineering[6]. They found that environmental engineering courses have a high contextual nature. We developed an IE for the Introduction to Environmental Engineering course, E188. This course has existed in its current form since spring 1996. E188 can be taken by sophomore, junior, and senior college students; the main bulk of the enrollment is senior engineering majors. The IE we developed involves having the college students each design a WebQuest for middle school students. The WebQuest must explore the connection between technology and society, and then present it as a web-based set of tasks, resources, and processes suitable for middle-school students.

A WebQuest is a web-based learning tool for K-12 students introduced by Bernie Dodge involving inquiry-oriented activities in which a large portion of the information required by the users is on the web[7]. A WebQuest is a web page or sets of linked web pages which detail the tasks to be performed by the K-12 students, and which includes hyperlinks to other web sites in order to provide information necessary to complete the task. WebQuests help direct the user's focus by teaching them how to use information rather than just searching for it, and then steers the learner towards analysis, synthesis, and evaluation of the newly-gained information. The instructional goal of a WebQuest is the acquisition of knowledge, and the subsequent integration[8]. At the completion of a WebQuest, a student will have gathered a significant amount of new information and made sense of it.

The WebQuests were designed for learners at the middle-school level. Middle school students were chosen as the desired audience because this allows the introduction of engineering and technology to students at an early and critical age[9-11]. Also, having the designers of the WebQuests--the college students--explain concepts to middle-school students forced the college students to think deeply about the connection between technology and society in order to clearly explain concepts to younger students with no engineering background.

The WebQuest concept is attractive to us as engineering educators because WebQuests are becoming a popular web-based tool in the K-12 curriculum and we wished to provide more engineering representation. WebQuests are easy to disseminate to other middle school students, since they are web-based. Since many K-12 students are familiar with the format of WebQuests, it may be simpler to introduce the students to engineering using a familiar tool. We also had contacts at Truman Middle School, a magnet school in Fontana, California, which gave us an opportunity to test the WebQuests.

Very few engineering WebQuests exist at this time. One example is the 'Cracking Dams' WebQuest designed at Cornell University as part of the National Science Foundation SimScience project[12]. The WebQuest was designed by Cornell University graduate students and professors, and included a computer simulation of cracking in a dam. The WebQuest also considered societal impact of dam technology by having the students consider the effects of dam failure. Polaha[13] includes many suggestions for designing WebQuests for elementary, middle, and high school students.

II. Goals and Design Considerations

Harvey Mudd College's curriculum committee states an Integrative Experience should involve:

- consideration of one or more issues involving the relationship of science or technology with contemporary society
- a substantial project and an oral presentation
- self-reflection and critical analysis
- interdisciplinary thinking involving technical fields, where appropriate
- the possibility of engaging in service-oriented outreach activities

The addition of WebQuest design to E188 satisfied the requirements for an Integrative Experience as judged by the Harvey Mudd College's curriculum committee. Based on the definition above, the goals for the college students included researching the relationship between society and technology in an environmental engineering context, and the communication of those relationships in order to stimulate enthusiasm and interest in middle-school students with no background in engineering. The HMC students are required to give an in-class presentation about their WebQuests at the end of the semester to satisfy the IE presentation requirement. The students will also provide the URL of their WebQuests, which are a set of html files residing on a local computer server.

Middle school students at Truman Middle School in Fontana, California tested the WebQuests. The students were enrolled in the seventh and eighth grades at Truman Middle School. Truman Middle school is a technology magnet school with a high percentage of Latino and African American students. The goals for the middle-school students include:

- discovering engineering in a context of a real-world environmental engineering problem
- investigating the relationship between engineering and society
- becoming more familiar with computer and the Internet
- gathering information and data
- analyzing, synthesizing and evaluating newly-gained information
- acquiring knowledge using the web.

For the design of the WebQuest, the college students were told the WebQuest should be accessible to middle-school students; have a component addressing the relationship between society and technology; include enough graphics to make it visually appealing and contain, at a minimum, the following (heavily indebted to Dodge[7]):

- An introduction to clearly state the purpose and provide some background information.
- An interesting, achievable task.
- A set of information sources needed to complete the task, which can include hyperlinks to web-based resources including web documents, experts available via e-mail or real-time conferencing, and searchable databases on the net. Information about sources such as books or other documents can also be provided.
- A clear description of the process the learners should follow in accomplishing the task.

- A means of organizing the acquired information. This can be accomplished with guiding questions, or directions to complete organizational frameworks such as timelines, concept maps, or cause-and-effect diagrams[8, 14-15].
- A conclusion that brings the task to a satisfying closure, recaps what they've learned, and perhaps encourages them to extend the experience into other domains.

The WebQuests can be group activities, with the students taking on specific roles within a scenario, which can increase student interest. The WebQuests may contain role-playing where members of the group take on certain personae (biologist, chemist, journalist, engineer, to suggest a few).

The students at Harvey Mudd College were given materials on WebQuests and access to previously written WebQuests. These were provided on-line, on the web page for the environmental engineering course. This web page consisted of links to Dodge's WebQuest site, some example WebQuests, and to pages that detailed the design and construction of a WebQuest (all of these links can be found at www3.hmc.edu/~cardenas/webquestlinks.html).

III. Classroom results

First we will discuss the results of the Harvey Mudd students' Integrative Experience, and then we will discuss the feedback received from the middle school students and teachers who tested the WebQuests.

A. Integrative Experience--Harvey Mudd College

In the introductory environmental engineering course, the college students each designed a WebQuest. All the students had previously taken a biology course in which they were required to design a web page, so the students had previous experience with web page design. Throughout the semester, the students handed in various parts of the WebQuest, starting with a description of their chosen topic and a general outline of tasks for the student. Subsequently, the students handed in a list of roles for the students (for the role-playing WebQuests), and the URLs for the websites to be used for research in the WebQuest. This piecemeal assigning of various parts of the WebQuest was done to help the students in organizing and managing their WebQuest design process. The final deliverables were the URL for a completed WebQuest, and an in-class presentation describing their WebQuest, including what they expected the middle-school students to gain from performing the WebQuest.

The students were allowed to choose their topics; the topics had to be related to environmental engineering and have a societal component. The students chose topics that included:

- nuclear and alternative energy
- conservation practices in agriculture
- the Los Angeles aqueduct
- a cyanide spill in Romania
- deforestation
- air pollution
- energy conservation and planning for a new community

The WebQuests may be found at www3.hmc.edu/~cardenas/studentwebquests.html. The students came up with varied ways of introducing middle school students to engineering topics and their relation to society. The WebQuest by junior chemist Clare Schoene focused on the construction of the Los Angeles Aqueduct and its environmental impact. The first task for the middle school students is to make a pictoral story of the events that took place while building the Aqueduct. The second task is to write a letter from the animals in the Owens Valley to William Mulholland (the chief engineer for the Aqueduct) to explain the effect the Los Angeles Aqueduct has had on their lives. Some of the questions posed to the students include

- What contributions did William Mulholland make to the science of dam building?
- Who gained financially from the aqueduct and why?
- How has the air quality in the Owens Valley and Mono Lake area been affected?

This particular WebQuest should be very interesting to the students at Truman Middle School, since it is so near Los Angeles and shows a real life application of technology.

Senior engineering student Brian Maul wrote a WebQuest on air pollution, automobiles and alternative fuels. The middle-school students are tasked with understanding what causes air pollution; its effects; the role of the automobile; what kind of alternative fuels exist; environmental impacts of alternative fuels; and the societal impact of each alternative fuel (in terms of cost to consumer, convenience, cost of production, safety and reliability.) The final task of this WebQuest is for the student to imagine that they are someone about to buy a new car, as a recent college graduate, a parent, or an older, wealthier businessperson. Based on this person's needs, preferences and the conclusions that they have drawn through this project, the student is to write an argument for which car they would buy, including support for their position with at least three facts from different sources. This is a good topic for the Fontana middle-school students, because 1.) Los Angeles and environs are so dependent on the automobile, 2.) Fontana is located in the San Bernardino County, an area with heavy smog problems, and 3.) the task to choose an automobile should spur personal interest.

Senior engineering student Michael Tapper wrote a WebQuest which involves the students learning about energy sources in order to choose the best source for a developing nation, Muddland. Figure 1 shows the introduction to this WebQuest. On the left side of the figure is the task bar for the WebQuest, which helps the students navigate through the quest. Characteristics of Muddland are given as part of the information in the web site, and the students are to consider both economic and environmental issues when considering their choice. The solution should include:

- The various types of energy sources Muddland should use.
- How much of each type of energy source Muddland will use.
- For each type of energy source used, how much this will cost Muddland.
- For each type of energy source used, what effects this will have on the environment.
- A comparison of the total cost of energy and the money Muddland has available.
- A defense of the tradeoff made between cost and environmental depletion.

This WebQuest is unique among those designed in this course in that it has the students perform arithmetic in order to come up with the solution to Muddland's energy needs. Information on

the energy sources include price as well as the amount of energy that source could produce per year.

Senior engineering student Nitya Chandran wrote her WebQuest about deforestation. It is a role-playing WebQuest. The team is to act as a research team for a fictional television reporter who is preparing a documentary on deforestation. The student roles include researcher, geographer, environmentalist, logger, and engineer. The "researcher" answers the questions of what deforestation is, why it is done, and how severe the problem is. A "geographer" will provide information on where deforestation occurs in the world. Chandran frames the issue of deforestation as having two sides, and assigns a team member to represent each side. The "environmentalist" will look at the negative environmental effects of deforestation, while the "logger" will look at the positive economic aspects. The "engineer" is responsible for finding ways in which the public can help decrease deforestation. The final product of this WebQuest is a presentation by the team, including some ideas on what can be done to decrease deforestation.

Senior engineering student Regina Gorenshteyn wrote her WebQuest on the winter 2000 cyanide spill into the Tisza River in Romania. This is also a role-playing WebQuest. The students' task is to write a newspaper article covering the event, which will be done by a teammate taking on the role of a journalist. Four people in the group will take on a role of an expert and will gather information in his or her area of expertise. A "chemist" will learn about cyanide and its effects on living organisms. An "environmental engineer" will learn more about river pollution, comparing this case with other known cases. This person will also research possible ways of fixing this problem. Figure 2 shows the beginning of the page the environmental engineer role-player will use to do research for the WebQuest. The "geographer" will learn more about Danube River. One teammate will take on a role of a local villager, who will try to see this accident through the eyes of someone who lives there. The "journalist" is to interview the "local villager" as well as the "experts" in order to educate him/herself before writing the article.

Although the course was evaluated, the students did not comment specifically on the WebQuest project. However, during the in-class presentations of the students' WebQuests, the students seemed very enthusiastic about presenting their projects, and participated fully in asking their peers questions about their WebQuests.

B. WebQuest--Fontana Truman Middle School

In order to evaluate the WebQuests, middle-school students at Fontana Truman Middle School used the WebQuests in class during spring 2000. The following comments were received from the middle-school teachers:

- "Good choice of topic--real life application"
- Colored backgrounds and useful graphical images make the design much better in terms of getting the students' interest.
- Giving clear objectives and telling the students what they are going to learn is good.
- "Good inclusion of a link to 'greenhouse effect' in the introduction. Many students would not know what that is and it is an important concept in the introduction."

- "Task--clear--gives team members specific jobs and responsibilities."
- "An oral presentation of research within a 'scenario' is a good project--it allows for the learning styles of all the students."
- "Very current and timely."
- "Brainstorming [is an] interesting way to get students actively participating."
- "Encourages them to take notes as they work."
- "Gives students a clear idea of what they will learn."

The following suggestions were made:

- The organization of the tasks could be better. Some quests begin without telling the students what they are going to do, whether it is an individual assignment or a team project.
- Including an evaluation section is necessary in order to know how the students' work was to be evaluated.
- A clear task is necessary. Some of the quests lacked a clear task; the students need to know what they will do with their information.
- Including references to future careers in the field would be helpful to the students.
- Extensions to some WebQuests would be useful; for example, it "could challenge students to investigate examples of chemical pollution in their own area."
- Do not restrict the students to on-line resources, and the WebQuests need to indicate that, since "if you don't tell kids they can use something else, they won't think of that themselves."
- Including teachers' pages would help in letting the teachers know the main goals of the WebQuests.
- "It would be helpful if the pages had the same or similar format. The middle schoolers got a little confused when trying to find things. A similar format would also help the teacher when they are having the kids look for something specific."
- "Some of the vocabulary was subject specific and it might help if there were a glossary of terms."

The overall response from the students and teachers was encouraging, as the students found the experience interesting and worthwhile.

IV. Summary and Future Work

As the integrative experience is required for all students to graduate from Harvey Mudd College, we intend to continue to have the students design WebQuests involving the integration of technology and society in E188. As we obtain more information from middle school students and their teachers regarding what works best, we will use that information to design better WebQuests. We already learned it is important to have enough graphics to catch the students' interest, and that the students particularly enjoyed maps. Navigation and organization issues are important in the WebQuests; some of the designed pages have a navigation bar that allows the students to easily move from page to page. However, some of the WebQuests have a much less efficient navigation system. In future assignments, navigation issues will be stressed. Per the

comments from the students, it may be wise to have a very similar format for all the WebQuests, so the students do not get 'lost' in the web pages. The WebQuests should be tested on several platforms and browsers to make sure they work on the most common ones. Adding teacher's guides to the WebQuests would probably help the middle school teachers integrate the WebQuests into their curriculum. The enrollment in E188 was small-eight students-and if enrollments increase, some organization of the students' chosen topics may be needed to avoid duplication. We plan a more formal assessment of the WebQuests in the future. We will most likely design surveys or questionnaires to determine the effectiveness of the WebQuests for the middle schoolers. Also, an online comments page will be linked to each WebQuest in order to receive user suggestions. As we become more experienced in WebQuest design, we intend to link our page of WebQuests to one of the more popular WebQuest pages for K12 educators so more students can use the quests and become aware of the role engineering plays in society and vice versa. We have also been considering extending the WebQuest concept to other existing courses, especially the fluid mechanics course, which already has large historical context.

Bibliography

1.) Criteria for Accrediting Engineering Programs, Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, Inc., Baltimore, MD, 2000.
2.) Herkert, J.R., "Science, Technology and Society Education for Engineers", *IEEE Technology and Society Magazine*, vol. 9, no. 3, 1990, pp. 22-26.
3.) Dick, K.J. and B. Stimpson, "A Course in Technology and Society for Engineering Students," *Journal of Engineering Education*, vol. 88, no. 1, 1999, pp. 113-117.
4.) Florman, S.C., "Learning Liberally," *ASEE Prism*, vol. 3, no. 3, 1993, pp. 18-23.
5.) Guilbeau, E.J. and V.B. Pizziconi, "Increasing Student Awareness of Ethical, Social, Legal, and Economic Implications of Technology," *Journal of Engineering Education*, vol. 87, no. 1, 1998, pp. 35-45.
6.) Vanderburg, W.H., and N. Khan, "How Well is Engineering Education Incorporating Societal Issues?", *Journal of Engineering Education*, vol. 83, no. 4, 1994, pp. 357-361.
7.) Dodge, B., 1997. "Some Thoughts about WebQuests", available online at http://edweb.sdsu.edu/courses/EDTEC596/About_WebQuests.html
8.) Marzano, R.J., "A different kind of classroom: Teaching with dimensions of learning", Alexandria, VA: Association for Supervision and Curriculum Development, 1992.
9.) Blaisdell, S.L. and M.R. Anderson-Rowland, "A Pipeline to Recruit Women Into Engineering", *ASEE Annual Conference: Engineering Education and the Information Revolution*, Milwaukee, Wisconsin, 1997.
10.) Cornwell, P.J., Stienstra, D., and S. Smith, "Fast Forward--An Adventure in Engineering for 7th and 8th Grade Girls", *ASEE/IEEE Frontiers in Education 95 Workshop*, IEEE Catalog # 95CH35867, 1995.
11.) Wilson, D., Hudson, T., Fletcher, S., Harris, B., Knight, C., Morris, T., Patel, G., and S. DeWeerth, "Establishing the Foundations for Engineering Education in K-5", *ASEE/IEEE Frontiers in Education 95 Conference*, IEEE Catalog # 95CH35867, 1995.
12.) Polaha, M.V., and A.R. Ingraffea, "Cracking Dams: An Interactive Web Site for K-12". Submitted for review, 2000.

13.) Polaha, M.V., "Cracking Dams: An Interactive Web Site for K-12". Master's Thesis, Cornell University, 1999.
14.) Marzano, R.J., Brandt, R.S., Hughes, C.S., Jones, B.F., Presseisen, B.Z., Rankin, S.C., and C. Suhor, "Dimensions of thinking: A framework for curriculum and instruction", Alexandria, VA: Association for Supervision and Curriculum Development, 1988.
15.) Clarke, J.H., "Patterns of thinking: Integrating learning skills in content teaching", Needham Heights MA: Allyn and Bacon, 1990.

MARY CARDENAS

Mary Cardenas is currently an associate professor of engineering at Harvey Mudd College in Claremont, California. She received her B.S. in Aerospace Engineering from Iowa State University in Ames, Iowa, her M.S. and Ph.D. in Mechanical and Environmental Engineering from the University of California at Santa Barbara. She worked as a propulsion engineer at Rocketdyne Propulsion Systems before her graduate studies. She teaches courses in design, systems, chemical engineering, environmental engineering, and fluids

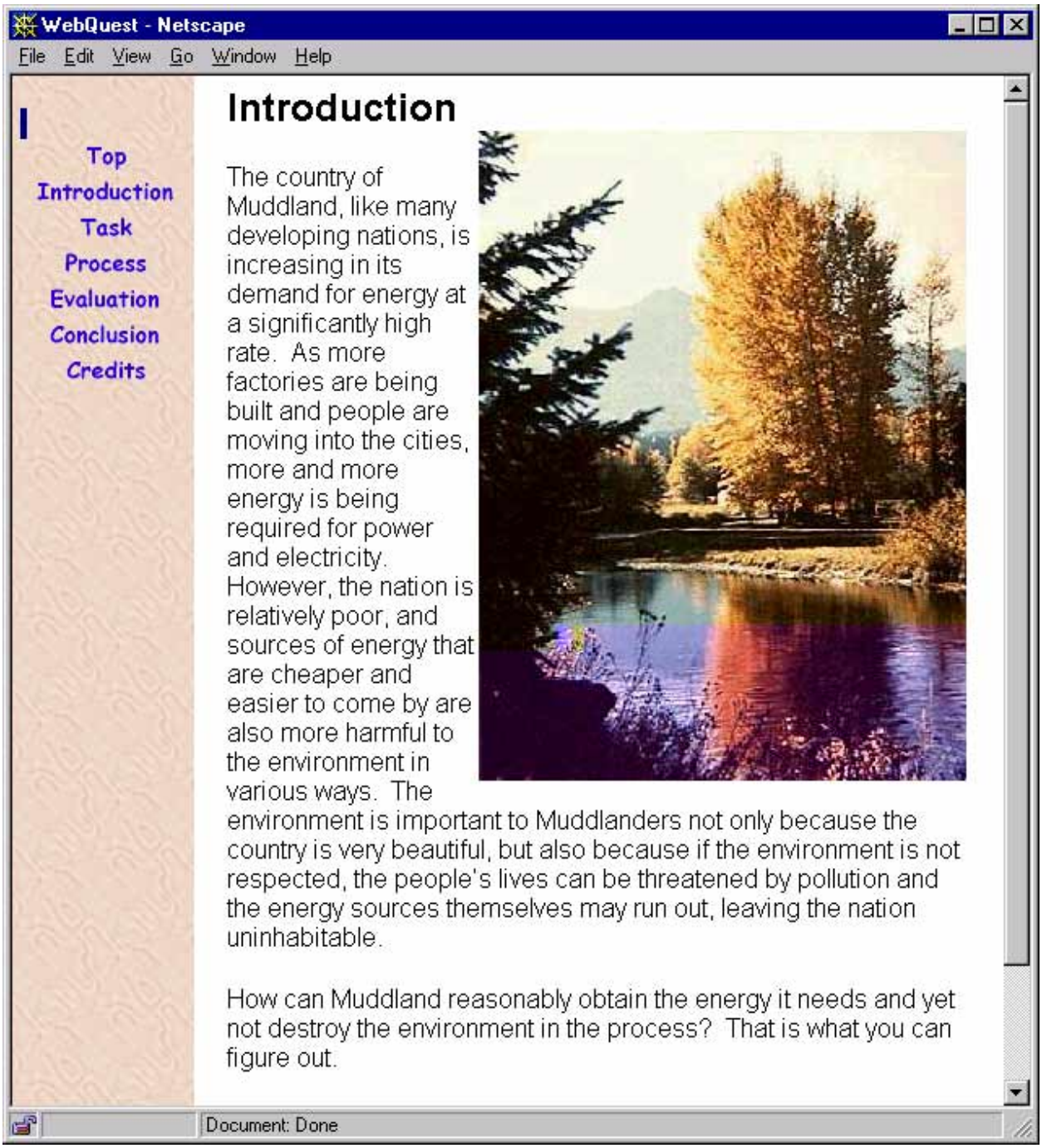

Figure 1. The introduction page from the WebQuest "Energy for Muddland."

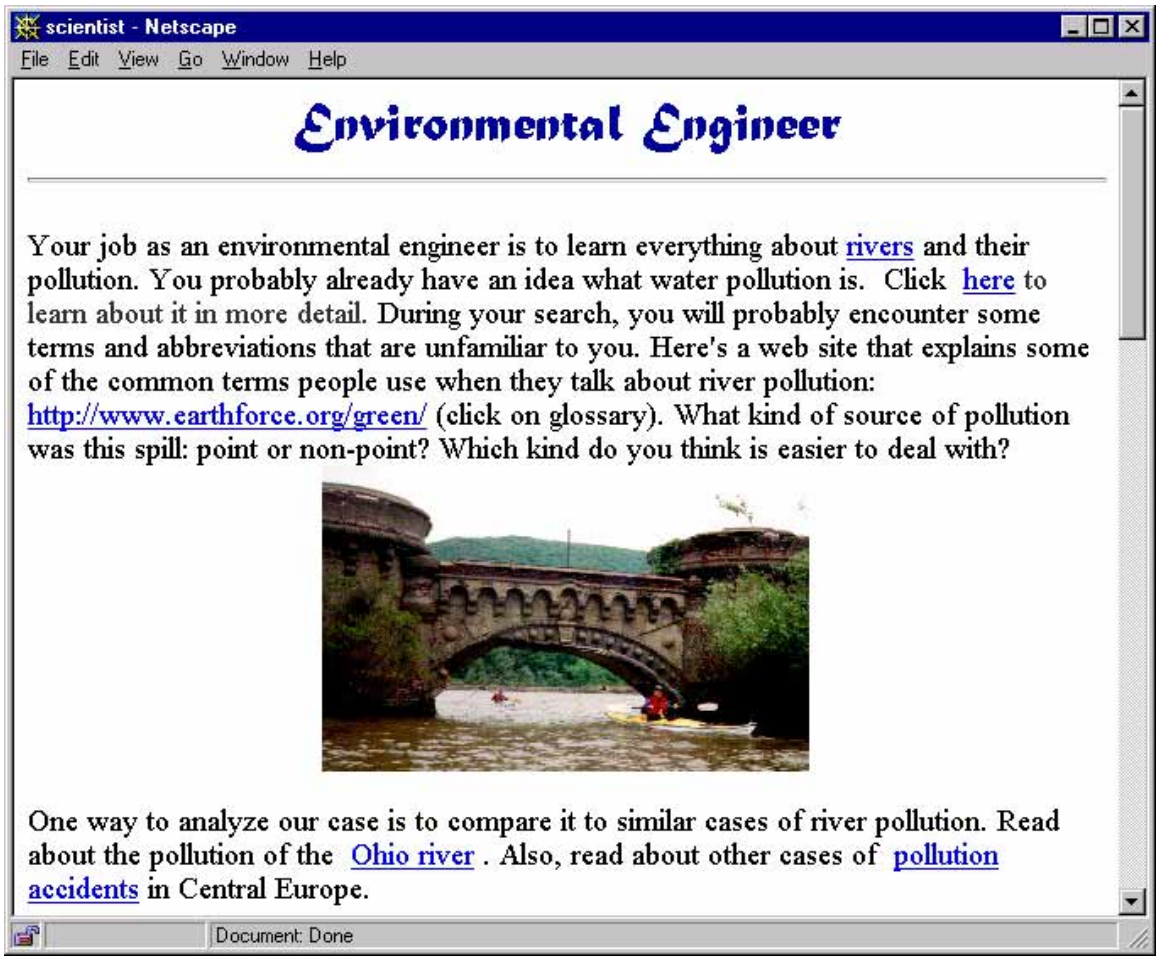

Figure 2. The page for the Environmental Engineer role from the WebQuest 'Romanian Cyanide Spill.'