The Implementation and Effects of Cognitive Tools in Environmental Literacy Courses

Thomas C. Reeves, Ph.D.
Instructional Technology
The University of Georgia
treeves@coe.uga.edu

James M. Affolter, Ph.D.
State Botanical Gardens of Georgia
The University of Georgia
affolter@uga.cc.uga.edu

Chor-Pang Lo, Ph.D.
Dept. of Geography
The University of Georgia
chpanglo@uga.cc.uga.edu

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Abstract: Funded by the National Science Foundation (NSF), Project RELATE (Realizing Environmental Literacy through Advanced Technology and Experimentation) is a collaborative effort of several departments at The University of Georgia (UGA), including Ecology, Geography, and Instructional Technology. The Georgia State Botanical Gardens, located near the UGA campus, serves as a living laboratory for the long-term, ecological research that is at the heart of this innovative program. The development work is being conducted within UGA's Learning and Performance Support Laboratory (LPSL). Detailed information about the project can be found on the World Wide Web: http://lpsl.coe.uga.edu/RELATE/Envirolit.html As of March 1998, more than 600 students have participated in Project RELATE with positive cognitive and affective results.

Overview

Project RELATE is focused on promoting Environmental Literacy by involving undergraduate students in long-term ecological research. Through Project RELATE, students enrolled in courses as diverse as ecology and geography are experiencing personally meaningful and socially important research activities while learning how environmental research studies are designed, implemented and analyzed. To support a high level of practical experience for the students, the State Botanical Gardens of Georgia, a 300-acre woodland located near the University of Georgia campus, serves as a living laboratory for a program of long-term, ecological research that is at the heart of this innovative project. Guided by a graduate research assistant, small teams of undergraduate students conduct several types of stream and forest experiments during two field trips to the State Botanical Gardens each academic term.

To prepare students for these outdoor research experiences, the project employs the World Wide Web to provide students with access to rich information resources about the labs in particular and environmental literacy issues in general. In addition, to support students during what for most of them is their first experience with actual research, the project uses computer software as cognitive tools for interactive data entry, analysis, and report preparation. These cognitive tools are accessible in computer labs located in the Ecology and Geography buildings on the main campus. This curriculum enhancement project is a collaborative effort of several academic departments at The University of Georgia (UGA), including Ecology, Geography, and Instructional Technology as well as the State Botanical Gardens and the Learning and Performance Support Laboratory (LPSL) (http://lpsl.coe.uga.edu/).

The Need

In 1993, Dr. Charles B. Knapp, then President of The University of Georgia, in collaboration with the University Council, decided that Environmental Literacy should be a component of study for every undergraduate at The University of Georgia. Several academic departments responded to this initiative by developing traditional survey courses to meet the new undergraduate requirement. A review of the syllabi for these courses indicated that the instructors teaching them primarily employed traditional higher education instructional strategies such as lectures, assigned readings, a term paper, and mid-term and final examinations. After considering both the advantages and disadvantages of these well-established pedagogical approaches, it seemed probable to the authors of this paper that these courses did not provide students with adequate authentic experience in natural environments to construct a lifetime commitment to environmental literacy. Therefore, the authors prepared a proposal to the National Science Foundation (NSF) to develop instructional strategies that emphasize experiential research in natural environments as well as to design a learning support system (LSS) using cutting-edge technologies such as the World Wide Web (WWW) and cognitive tools (Jonassen, 1996; Jonassen & Reeves, 1996).

Purpose, Goals, and Objectives

The ultimate purpose of Project RELATE is to create an effective learning environment to help undergraduate students develop environmental literacy, so that they become responsible citizens who take care of the limited natural resources of our planet. To accomplish this purpose, two major components were developed, implemented, and evaluated:

1. Field experiments at the State Botanical Gardens of Georgia that enable students to participate in long-term ecological research and to learn the principles of experimental design, data collection, and data analysis.
2. An effective, user-friendly computer-based learning environment that promotes and supports Environmental Literacy within the student community.

The general goals of Project RELATE are to:

1. Expose students from a broad diversity of backgrounds and interests to fundamental scientific concepts such as research methodology and analysis.
2. Demonstrate to students the importance of environmental and biological variation measured over space and time in the study and understanding of natural systems.
3. Strengthen geography skills and familiarize students with the purpose and use of computerized geographic information systems (GIS).
4. Create interest in scientific research and science education as career opportunities, as well as foster a lifelong commitment to environmental literacy.
5. Increase the information content, and therefore the value, of the State Botanical Gardens of Georgia as a teaching resource.

The specific instructional development objectives of this project were to:

1. Develop a Geographic Information System (GIS) for the State Botanical Gardens of Georgia that provides the framework for the presentation and analysis of long-term ecological studies.
2. Design several laboratories that test hypotheses concerning ecological processes in the Gardens' natural forest and stream communities.
3. Develop an interactive multimedia learning support system (LSS) that guides students through the research experience by using simulations, tutorials, and other support tools, and that assists them in using the GIS interactively.
4. Implement and evaluate the use of the laboratories, including the interactive multimedia LSS, in selected environmental literacy courses at The University of Georgia, and at other institutions in the future.

What Is Environmental Literacy?

Environmental Literacy is a skill that is now and will continue to be in high demand in the coming decades. It can be briefly defined as the ability to comprehend and critically evaluate:

1. basic principles which govern natural systems,
2. linkages among living organisms and the physical environment, and
3. consequences of human activity on natural systems.

Environmental literacy also encompasses attitudes that support a lifelong commitment to protecting and enhancing the environment on local and global levels. Vice President Al Gore (1992) and other political and social leaders have emphasized the importance of global environmental literacy in the 21st Century.

Curriculum

Three experimental laboratories within three different fields of research (stream ecology, forest ecology, and geography) have been developed and used in Ecology 100 and Geography 200 courses offered during the past three academic years (1995-98). For the Stream Ecology and Forest Ecology labs, students access introductory material on the World Wide Web at the Environmental Research Support Site (http://lpsl.coe.uga.edu/projects/ERSS/home.html). A virtual host (a beaver) greets them on the steps on the Environmental Research Center to which they have been assigned as interns. (See Figure 1 for an illustration from the program.) After the orientation, students then travel to the State Botanical Gardens of Georgia, located two miles from the main campus, to collect data at several different stream sites and forest plots. Once they have their field data in hand, students return to a computer lab in the Ecology Building to complete the data analysis and prepare their reports. Thus, students enrolled in these courses become active participants in long-term ecological studies that require them to test formal hypothesis based on data they collect in the field.

Figure 1. Illustration of the beaver who serves as the virtual host in Project RELATE.

For example, to investigate water quality in streams at the Botanical Gardens and on the UGA campus, students conduct macroinvertebrate bioassessments in the streams, perform cross section analyses, and do pebble counts. This laboratory follows the protocol given by the Izaak Walton League's "Save Our Streams" program (http://www.iwla.org/iwla/). The students make qualitative observations about the watershed surrounding each stream (for example, types of vegetation present, color of the stream bottom, presence or absence of leaf litter on the surface of the water, etc.). Then, they work in groups of four to six to count and identify the invertebrates present in different samples from the streams. Using the cognitive tools in the computer labs, the students generate hypotheses concerning the differences in bioassessment results in the different locations, analyze their data, and prepare research reports concerning their findings. The students collect real data in the Botanical Gardens streams themselves, whereas the data from the stream on the main campus is provided to them because that stream is too polluted to allow students direct access. Graduate research assistants and faculty regularly collect data from the polluted stream wearing bio-protection suits.

In the Forest Lab, the study sites are permanent 20 x 20 meter plots located at the State Botanical Gardens of Georgia. Students work in groups of three to record the number, species, and diameter at breast height (dbh) of all trees that have a dbh greater than 3 cm. They are also required to make qualitative observations, and to take soil cores. Each team of students follows this procedure in two plots with different land use histories. The students also make qualitative judgments and take soil cores in a flood plain forest area. As before, their field research is integrated with hypothesis generation, data analysis, and reporting activities within the computer lab supported by the cognitive tools in the Learning Support System (LSS).

Role of Technology

Whereas many instructional technologies are designed to function as electronic tutors, in Project RELATE, technology is used as a Learning Support System (LSS) within the context of undergraduate courses that emphasize experiential learning. The overall LSS includes simulations, tutorials, and research support tools. In Project RELATE, computer programs are employed as "cognitive tools" to support student learning rather than as a device for transmitting the content of instruction (Jonassen & Reeves, 1996). This is a distinct departure from traditional approaches to employing technology in higher education.

Cognitive tools have been around for thousands of years, ever since primitive humans used piles of stones, marks on trees, and knots in vines to calculate sums or record events. In the broadest sense, cognitive tools refer to technologies, tangible or intangible, that enhance the cognitive powers of human beings during thinking, problem-solving, and learning. Something as complex as a mathematical formula or as simple as a grocery list can be regarded as a cognitive tool in the sense that each allows humans to "off-load" memorization or other mental tasks onto an external resource. Today, computer software programs are examples of exceptionally powerful cognitive tools (Jonassen, 1996; Lajoie & Derry, 1993). Also referred to as "cognitive technologies" (Pea, 1985), "technologies of the mind" (Salomon, Perkins, & Globerson, 1991), and "mindtools" (Jonassen, 1996), the term "cognitive tools" is widely used today (Kommers, Jonassen, & Mayes, 1992; Jonassen & Reeves, 1996).

Computers as cognitive tools represent quite a different approach from computers as vehicles for educational communications. Computer-based cognitive tools have been intentionally adapted or developed to function as intellectual partners to enable and facilitate critical thinking and higher order learning. Examples of cognitive tools include:

- databases,
- spreadsheets,
- semantic networks,
- expert systems,
- communications software such as teleconferencing programs,
- on-line collaborative knowledge construction environments,
- multimedia/hypermedia construction software, and
- computer programming languages.

In the cognitive tools approach, information is not encoded in predefined educational communications which are then used to transmit knowledge to students. Indeed, with cognitive tools, the need for formal instructional systems design processes are reduced. Instead of specialists such as instructional designers shaping students' learning via prescribed communications and interactions, computers are given to learners to use for representing and expressing what they know. Learners themselves function as designers using media and technology as tools for analyzing the world, accessing and interpreting information, organizing their personal knowledge, and representing what they know to others.

Within Project RELATE, the use of cognitive tools is contextualized for the students within a simulation that enables students to become interns at an ecology research center. In the simulation, students sign on as interns in a simulated environmental research center where they are given their field assignments, learn about various aspects of research design and environmental literacy, and use data analysis tools to prepare research reports. Figure 1 illustrates some of the scenes from the Project RELATE simulation.

The development work for Project RELATE was conducted within UGA's Learning and Performance Support Laboratory (LPSL), a research and development facility supported by the Georgia Research Alliance, NSF, and several corporate sponsors. The prototype versions of the LSS for the field research labs in Ecology 100 courses was developed in Macromedia Authorware Professional for delivery on Apple Macintosh computers. The forest ecology laboratory also incorporates a GIS data analysis component, developed in ArcView for the PC and Macintosh. A third laboratory has been developed in ArcView for use in Geography 200 classes. The latest version of the LSS is being modified for distribution over the WWW, with the ultimate goal of enabling students to access the cognitive tools in the LSS anywhere they have access to the Web. This is viewed by the collaborating faculty as a significant step toward creating a WWW-based learning environment (Khan, 1997).

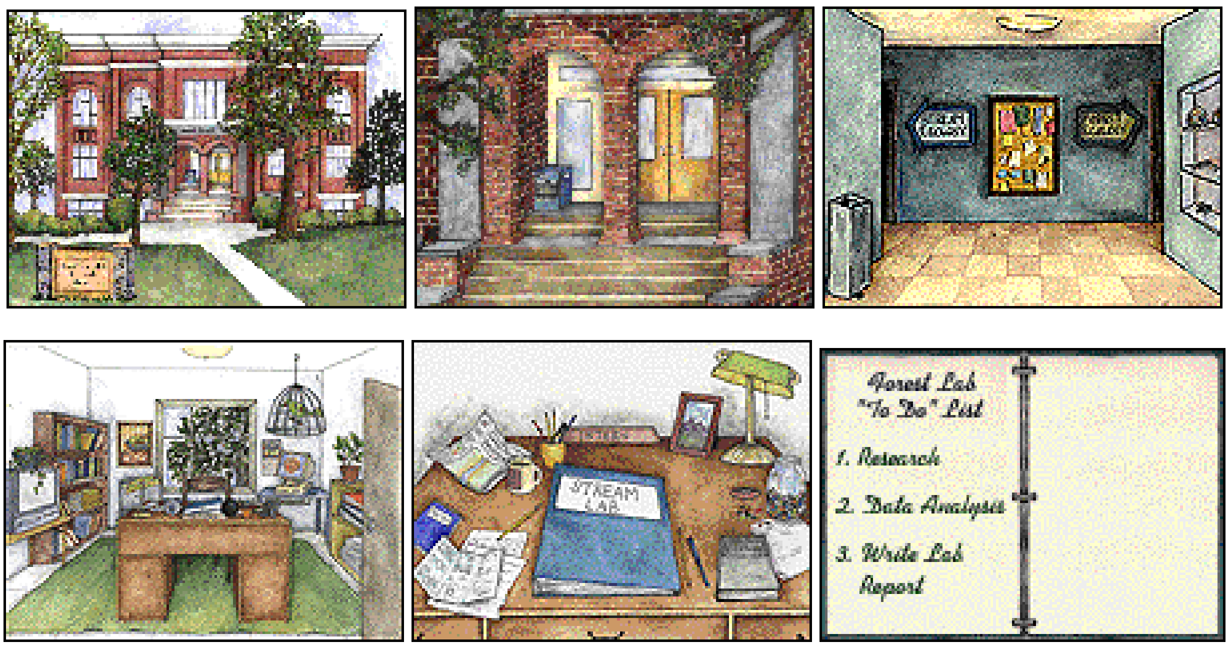

Figure 1. Scenes from Project RELATE simulation.

Implementation and Results

This project was funded by a grant from the National Science Foundation's "Leadership in Laboratory Development" program. This collaborative effort involved four university units: the Department of Geography, the Department of Instructional Technology, the Institute of Ecology, The State Botanical Gardens. In addition to cooperating faculty from Ecology and Geography and the principal investigators (Dr. James M. Affolter, Dr. Chor Pang Lo, and Dr. Thomas C. Reeves), the Project RELATE TEAM included: Mike Buoy, Graduate Student, Department of Instructional Technology, David Handaly, Graduate Student, Department of Horticulture, Carrie Gahagan, Graduate Student, Department of Instructional Technology, Emily Pritchard, Graphic Artist, Athens, Georgia, Jennifer Tougas, Graduate Student, Department of Ecology, and Kai Wang, Graduate Student, Department of Geography.

As of March 1998, over 600 students have participated in the field research using the Project RELATE LSS. The labs have been implemented successfully each academic term despite the vagaries of weather (e.g., rain that turns the Gardens into a swamp) and season (e.g., ticks and snakes in the summer). Transportation to and from the Gardens is provided by university vans and each team of students is led by a graduate research assistant or faculty member. The lack of space in the Ecology building meant that the computer lab had to be set up and taken down each time these programs were used during the first two academic years, but fortunately a permanent space for the computer lab has been found this year.

Formative evaluation data from these field trials have been used to refine the LSS which uses a 2-D virtual reality user interface. Each time the research procedures and the cognitive tools have been enhanced, both students and faculty have reported increased satisfaction with the field research experiences and the LSS. Ecology 100 students consistently perform better on final examination questions related to the field research labs than on the questions drawn from any other parts of the course such as lectures and assigned readings. In light of these findings, the participating faculty have committed themselves to continuing to use the Project RELATE labs and the LSS after the NSF grant is completed in June 1998. Further evidence of the faculty commitment to the continued integration of Project RELATE into environmental literacy classes is the fact that the School of Ecology is now funding the graduate assistant who maintains the Project RELATE computer-based learning environment.

Efforts to disseminate the Project RELATE materials to other higher education institutions are underway, and a proposal is being developed to develop a similar approach for secondary education in collaboration with the Fernbank Science Center in Atlanta, Georgia. The authors of this paper actively seek collaborators in this long-term research and development program. For anyone interested, detailed information about the project can be found on the World Wide Web: http://lpsl.coe.uga.edu/RELATE/Envirolit.html

Summary

The ultimate goal of Project RELATE is to create an effective learning environment to help undergraduate students develop "Environmental Literacy" and become responsible citizens who care for the earth. This is an important goal at UGA where every undergraduate is required to complete at least one Environmental Literacy course. As noted above, most of the courses meeting this requirement utilize traditional instructional methods such as attending lectures, reading textbook assignments, writing term papers, and taking tests. By contrast, Project RELATE combines innovative pedagogy (experiential learning through authentic field research) with the use of technologies (cognitive tools) that "scaffold" students' development of environmental literacy and research skills. In other words, Project RELATE is focused on developing a constructivist learning environment (Wilson, 1996) with both real-world and simulated aspects. The effectiveness of this learning environment will be monitored in coming years, and if the results continue to be positive, dissemination efforts will be expanded.

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