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ABSTRACT

This paper presents the results of three years of development and evaluation of a CD-ROM/Web hybrid simulation known as Brownfield Action for an introductory environmental science course at an independent college for women in the northeastern United States. Brownfield Action is a simulation that provides a learning environment for developing the skills of an environmental site investigator by placing students in a virtual town and asking them to serve as consultants to a real estate developer who wants to avoid purchasing potentially contaminated land. Students must become actively involved in the lecture and laboratory in order to succeed. They work collaboratively with a partner in order to reach a valid conclusion. Results are summarized as follows. Students learned more and in greater depth using Brownfield Action than in previous years without it; student work looked more authentic and professional, closer to what would be expected of a professional performing these tasks; students appreciated how the simulation contributed to their understanding of the material; Brownfield Action was successful in enhancing the scientific literacy of students, facilitating their construction of new meaning based upon what they saw and experienced, and enhancing practices leading to increased student learning; students' abilities to construct new meaning based upon what they saw and experienced were expanded; students found the content useful and the simulation a good way to learn it; more staff development is necessary to foster the teaching strategies needed for a true discovery process and to build comfort with technology; minor technical glitches created levels of frustration that interfered with its ability to meet its educational potential, however students gave high ratings to other features of the technology, and in particular, eight out of ten students noted the ease with which it was possible to move through information in each of the sections of the simulation. In all, the project has proved successful in providing students with a more integrated science experience than in traditional classrooms. (AEF)

Brownfield Action: An Integrated Environmental Science Simulation Experience for Undergraduates

By: Ryan Kelsey

Brownfield Action: An Integrated Environmental Science Simulation Experience for Undergraduates

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Objectives

The purpose of this paper is to present the results of three years of development and evaluation of a cd-rom/web hybrid simulation known as Brownfield Action for an introductory environmental science course at an independent college for women located in a large city in the northeastern USA.

Perspectives

Science courses often struggle to link the material in lecture and laboratory for many reasons. Laboratories are often taught by different personnel, and must fit into constraints of equipment and time, as well as safety and level of difficulty. A large survey course may cover dozens of topics, whereas a student typically experiences no more than fifteen laboratory periods in a given semester. Larger than these logistical issues is the student's mindset in each environment. Life science lectures require rapid note taking and passive concentration as verbal information is drilled at students for anywhere from one to two hours. Laboratory sessions typically require two to three hours of recipe-following and occasional problem solving. These two functions operate in isolation because there is little time in lecture to discuss experimental technique (if the lecturer even knows that information) and a laboratory is not typically set up for someone to give verbal instruction as occurs in the lecture hall. But more than these aspects, typical science students spend most of their time memorizing verbal information for lecture exams, and memorizing techniques, anatomy, and taxonomies for laboratory practical examinations. Rarely is information from one used in the other simply because the lecture focuses on concepts while the laboratory teaches technique. Students often walk away from a course feeling as if it were two courses and fail to get a sense of the content as a whole.

Simulations provide the ability to integrate content into a complex problem that students can explore. The closest work to the experience of the Brownfield Action design and development process can be seen in Goodrum, Dorsey, and Schwen's work on defining and designing Enriched Learning and Information Environments (ELIEs) (*Educational Technology* November 1993). In this paper, the researchers describe how their experience with designing educational environments led them away from entirely technology-based and theory-based definitions and more towards what they define as a socio-technical definition that focuses on the people involved and the specific work they are asked to perform. They perceive that the latest learning theory and the latest technology does not lead to innovation, but instead that all innovations are situated within a context of people trying to accomplish work in a particular environment, and a well-designed teaching and learning tool should support that work. They go on to describe their design work as a series of relationship building with users, rapid prototyping with mock-ups and a focus on the tasks that users needed to perform. The Brownfield Action project follows a similar model.

Methods

Columbia University's Center for New Media Teaching & Learning (CCNMTL) developed and implemented a cd rom/web hybrid simulation known as Brownfield Action in the Fall of 1999 and again in the Fall of 2000 at an independent college for women located in a large city in the northeastern USA, which models how an undergraduate Environmental Science course can directly integrate its lecture and laboratory components. Through presenting students with a complex problem that requires the application of knowledge and skills learned in lecture and in the laboratory setting, performance and engagement is improved, and students experience environmental science as a highly integrated field while developing real-world problem solving skills. Rather than reserving higher level thinking skills such as analysis and synthesis for smaller, more advanced courses, Brownfield Action allows introductory students to see environmental science as an integrated and dynamic part of society, rather than a series of abstract concepts and recipe-driven techniques.

Brownfield Action is a simulation that provides a learning environment for developing the skills of an environmental site investigator by placing students in a virtual town and asking them to serve as consultants to a real estate developer who wants to avoid purchasing potentially contaminated land. Students must become actively involved in the lecture and laboratory in order to succeed. They must learn to explore and discover a path to a solution to the problems they encounter and work collaboratively with a partner in order to reach a valid conclusion.

Pairs of students form environmental consulting companies to investigate a hypothetical abandoned factory site in a small town. A mall developer who wishes to purchase the factory site contracts with each two-student company to conduct an investigation, write a report recommending a course of action, and construct maps of the site's basic geology, topography, and any contamination they discover.

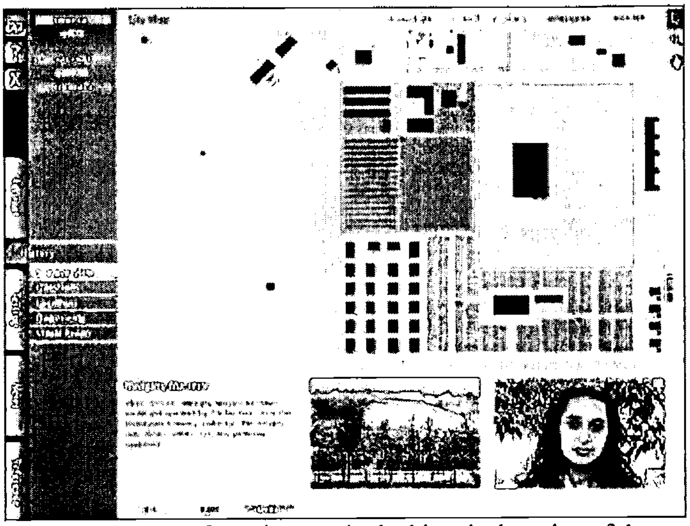

Figure 1. A screen capture of the site map in the historical section of the application.
The user is preparing to interview the owner of the local nursery in the town.

To complete the maps and report, students must first gather a site history from the town's resources. Through the simulation, students visit government offices, businesses, and residences to conduct interviews with town's officials and citizens and to obtain public documents (Figures 1 and 2).

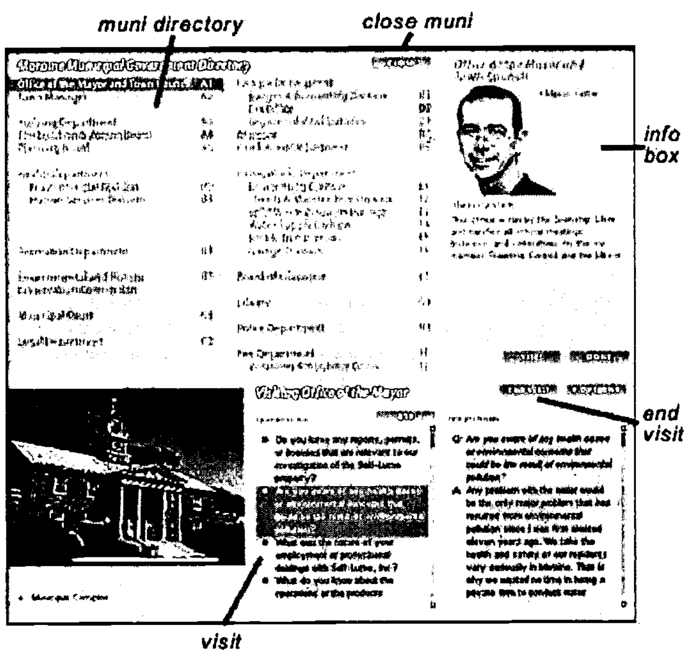

Figure 2. A screen capture of the municipal directory where students visit government offices.
The user is interviewing the township mayor.

Using the information obtained from the town's history, students then conduct a series of environmental tests to determine the presence, extent, and probable cause of any contamination. Some tests, such as soil permeability, are conducted as traditional laboratory exercises placed within the context of the simulation. Other tests, such as well monitoring, are conducted virtually using the computer. Over two million data points are available for collection over the 64,000 square foot virtual site map, including bedrock and water table data as well as contamination concentrations at depths of over 150ft. This vast quantity of data, both through the site history and the environmental testing, allows for an infinite number of strategies for testing and a unique data set for every student company. Successful students work within the given operating budget and clearly identify the cause and extent of the contaminated areas on the site.

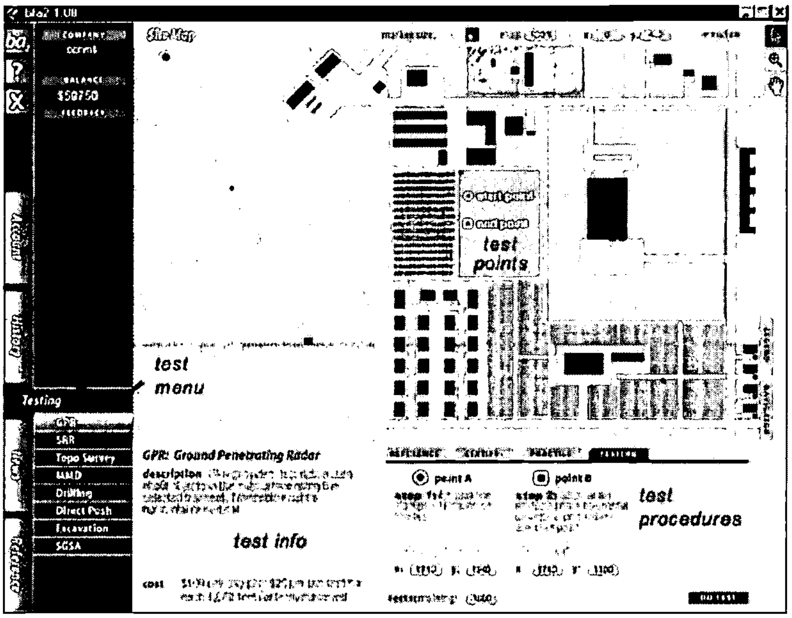

Figure 3. A screen capture of the testing interface.
The user is preparing to use the Ground Penetrating Radar test on the Site Map.

Brownfield Action is not intended as a cost-cutting measure, a time-saver, or a replacement for other material, but as a method of integrating what was formerly disparate labs and lectures into a seamless learning experience that improves student learning and motivates students to critically consider the importance of all the issues involved in the system of human impact on the environment.

The primary faculty member, serving also as the subject matter expert, identified the following objectives:

After experiencing Brownfield Action, students will be able to explain how to approach and solve a scientific problem by:

- describing the strategy used to discover contamination sites in Brownfield Action;
- identifying and explaining the outcomes of environmental tests they conduct and related information, making recommendations and being aware of the consequences of their decisions;
- drawing inferences from data about structures that contribute to environmental contamination;

and students will:

- read articles on ecology with different understanding, interest, and personal commitment;
- appreciate that real world decision-making about ecology involves ambiguity rather than certainty.

To assess the effectiveness of the second version of Brownfield Action (BfA2.0) that ran in the Fall of 2000 in meeting its objectives, students were surveyed at the beginning of the simulation to obtain an indication of their perceptions of the levels of knowledge and skill targeted by the course with which they started. The laboratory directors prepared a daily implementation log providing detailed documentation of the BfA2.0 experience in the labs. The evaluators observed five lectures and six of the three-hour labs to further their understanding of the instructional setting within which the Brownfield Action simulation was conducted. At the end of the course, students rated Brownfield Action on how well it had contributed to the objectives of the course and other matters, and all students participated in hour-long focus groups to provide in-depth responses to questions not amenable to discovery through written survey questionnaire. The evaluators also conducted hour-long, post-course interviews with the lead designer of the simulation; the primary faculty member (subject matter expert), and the laboratory directors. Finally, a cross section of the papers prepared by BfA2.0 students was reviewed and compared with student papers from previous years.

Data Sources

The entire course of one hundred and twelve female students were surveyed using two questionnaires (one at the beginning of the semester, one at the end) and a series of focus groups at the end of the term (one for each of the eight lab sections).

In the survey questionnaire and focus groups we investigated students'

- perceptions of pre- and post-test levels of their knowledge;
- perceptions of the success of BfA2.0 in meeting its objectives;
- perceptions of the contributions of various components of BfA in assisting them to solve the overall problem addressed by BfA2.0, and how well BfA2.0, the lectures and the lab succeeded in directing them to focus on the major problem addressed by BfA2.0.
- overall evaluation of BfA2.0, positive and less positive;
- recommendations for technical improvements in BfA2.0;
- perceptions of the most valuable parts of BfA2.0;
- perceptions of what could be done to improve BfA2.0.

The evaluation team also examined students' final reports in accordance with the learning objectives outlined by the primary faculty member as well as the daily laboratory implementation log prepared by the laboratory directors.

Summary of Results

- Students learned more and in greater depth using Brownfield Action than in previous years without it.
- Student work looked more authentic and professional, closer to what would be expected of a professional performing these tasks.
- Students appreciated how the simulation contributed to their understanding of the material.
- Brownfield Action was successful in (1) enhancing the scientific literacy of students, (2) facilitating their construction of new meaning based upon what they saw and experienced and (3) enhancing practices leading to increased student learning.
- Students' abilities to construct new meaning based upon what they saw and experienced were expanded.
- Students found the content useful and the simulation a good way to learn it.
- More staff development is necessary to foster the teaching strategies needed for a true discovery process and to build comfort with technology.
- Minor technical glitches created levels of frustration that interfered with its ability to meet its educational potential. These glitches notwithstanding, the students gave high ratings to other features of the technology. In particular, eight out of ten students noted the ease with which it was possible to move through information in each of the sections of the simulation.

Discussion

The simulation in the context of Brownfield Action is not just in the technology, but in the classroom environment set up around and supported by the technology. The simulation is in the course curriculum, the faculty member, the lab directors, and the students, and it only becomes a simulation once all of these factors work in parallel. For as long as there has been computing, many have tried to *simulate* aspects of reality with computing power, but the reality is that all that has been built to date might be better called *simulators*. Simulators model real-world processes with mathematical equations and variables that can be manipulated so that changes can be observed and analyzed. The software for Brownfield is no different upon close inspection. It is a model of a town with a mathematically driven contamination event that occurs within a narrative, but the narrative does not exist without the students fulfilling their role as investigators. In other words, the story does not get carried out unless the students and faculty pursue their roles and fulfill their tasks, or in effect, write their parts of the story as they interact with the simulator. Brownfield Action could be run in a classroom without any technology at all, and in fact it was done on a smaller scale for many years using an elaborate note card scheme. The computer software supports the expansion of the simulation created in the classroom, giving it a visual space, a more efficient process for collecting data, a means for communication, and more definition and depth (literally and figuratively) to the environment that is to be examined. The software itself does not teach. Instead it invites the user to engage in the problem. To foster engagement, one needs motivation and a safe space to take risks, and that is where the surround, the classroom, the curriculum, and the instructors come in to play.

Simulations can be powerful teaching and learning environments because operating in the real world is not really all that different from participating in a simulation. Everyone has roles to play in the real world (probably more than one), and there are problems, conflicts, and obstacles to be encountered and overcome in each of those roles. The method for overcoming these problems is in communication and experimentation, which includes hypothesizing, collecting data, analyzing, synthesizing, and applying previous discoveries with other role players using the tools that are available. One of the tools available in Brownfield Action is the software, but there are also physical maps, soil samples, reference material, and other similar narratives such as *A Civil Action*, a novel all students in the course read. Most any profession is going to place people in a similar situation and demand the same action from its participants. Brownfield Action provides a safe environment, away from the consequences of the real world – the money involved isn't real, one's job isn't at stake, etc… - so students can essentially practice living in the real world by immersing themselves in the problem to be solved in the simulation.

As outlined in studies such as Sandholtz's *Teaching with Technology: Creating Student-Centered Classrooms*, instructors need to phase out traditional directed or didactic teaching techniques and work towards more guiding and exploring strategies for teaching with technology to be most effective. This has proved true with Brownfield Action as well, so in preparation for this year's course, we instituted more staff development for the laboratory directors to assist them in improving their instructional techniques as well as a study guide to aid students in orienting themselves to the project.

All known technical glitches from last year's experience have been remedied for this year's course, but minor problems may continue to appear as they would with any project of this magnitude. Over time the instructors and support staff will only get more accustomed to the common problems students experience, so the effects of these problems should be minimal.

All in all, the project has proved successful in providing students with a more integrated science experience than in traditional classrooms and CCNMTL (http://ccnmtl.columbia.edu) looks forward to developing more simulation models for teaching and learning based on this project.

References

Goodrum, Dorsey, and Schwen (1993) "Defining and Building an Enriched Learning and Information Environment," *Educational Technology*, 33(11):10-20.

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