Session 2251

Interactive Site Investigation Software to Drive a Design Project in Contaminant Hydrogeology: Successes, Failures and Future Developments

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Abstract

This paper summarizes the past efforts and proposes future developments associated with a major educational development intended to serve as a problem-based learning environment for helping students to gain a deeper understanding of theory-based course content while accelerating their exposure to the practical aspects of an engineering design project. The curriculum development centers on an environmental engineering design project simulator called Interactive Site Investigation Software (ISIS). This paper reviews the background work and development of ISIS, as well as the instructional applications from 1999 through 2003 and the main educational assessment of ISIS in 2000. ISIS successes are documented and include the significant stimulation of lower achieving students, the major instructor time-saving aspects associated with automating such a project, and others. ISIS failures include an apparent lack of dissemination of ISIS to other instructors, and the related lack of educational assessment due to small ISIS test beds to date. Potential solutions to these problems, including ISIS workshops and user groups, are discussed. Future ISIS developments are proposed and may encompass inter-campus cyberteams comprising multi-disciplinary student teams and similar groups of on-line instructors and/or evaluators.

I. Introduction

This paper provides an overview of the development and application of a major environmental engineering instructional software package known as Interactive Site Investigation Software (ISIS). ISIS is job-environment simulator for the specific environmental engineering problem of hazardous waste site assessment. The software executes an interactive database that was custom-developed in Java for creating an environment where students could engage in a simulated site investigation.

Details about the workings and capabilities of ISIS are chronicled elsewhere (Harmon et al., 2002). In short, ISIS packages an instructor-fashioned three-dimensional soil and contaminant distribution in the context of a realistic subsurface environmental site assessment scenario. The students are then charged with the managing data collection under time and budget constraints, and interpreting their data in a consulting-style report.

The purpose of this paper is to provide instructors with an accurate impression of the level of effort and expected payoff of this type of instructional software. The paper provides an overview of the development, application, and educational assessment of the ISIS package. Throughout this overview, significant pitfalls and failures associated with the effort are presented. The paper concludes by outlining possible improvements and extensions of the ISIS package.

II. ISIS Developmental History and Resource Requirements

ISIS was conceived as a means of automating the administrative aspects of a student design project in contaminant hydrogeology. This design project was administered manually throughout the 1990s and cost the instructor and teaching assistants in excess of 25 hours per week over the four to five weeks of the project. A grant from the NSF Combined Research-Curriculum Development Program was used to develop ISIS. A timeline documenting the effort behind this development is shown in Table 1.

Table 1. Resources Expended Toward the Development of ISIS.

Category	1997	1998	1999	2000
Capital expenditures:				
SGI Workstations	$20,000	$14,000	$2,600	$0
Supporting software	$1,500	$1,500	$1,500	$700
Misc. hardware	$1,200	$1,200	$1,200	$0
Technical personnel:				
Content providers	1 @ 20%	2 @ 10% each	2 @ 10% each	1 @ 10%
Java™ Programmers	1 at 50%	1 @ 100%	2 (100%, 50%)	1 @ 25%
Assessment personnel:				
Content provider	--	2 @ 5% each	1 @ 5%	1 @ 10%
Assessors			1 @ 25%	1 @ 50%
Animation personnel:				
VRML™ Programmers	1 @ 50%	1 @ 50%	--	--

The total direct cost of the ISIS was approximately $225,000 of which included roughly $35,000 was hardware, software and supplies, $35,000 for the educational assessment, and the remainder for programming. In general, the funds were sufficient, mainly due to the generosity of several of the co-principle investigators who voluntarily declined any summer salary throughout the project.

Perhaps the most valuable person associated with the ISIS project was the lead programmer. This person (J. Giron) had an educational background uniquely suited for the project. At the onset of the project, he had just completed his M.S. in Water Resources Engineering, so he was intimately familiar with the work tasks to be simulated in ISIS. At the same time, Giron, like many engineering students in the mid-to-late 1990s, was interested in pursuing a career in computer science/programming, and was therefore learning to program in Java™, which was a relatively new language at the time. Thus, ISIS offered this person a

chance to hone his programming skills, and relieved the content providers from having to communicate the details of the desired ISIS features in great detail. A disadvantage of this was, however, realized later when the lead programmer left for employment in the information technology sector. At this stage, an undergraduate in computer science (W. Wong) replaced him. While excellent as a programmer, this person required a much more detailed description of the features he was coding. Thus, the content providers had to learn to provide these details, which they related to the programmers via program flow charts.
Perhaps the largest problem associated with the ISIS development was the Silicon Graphics operating system (IRIX) chosen for the development phase. This choice was made to facilitate the proposed link between the Java-based ISIS work simulation software and the three-dimensional animation that was to accompany it. The animation software was being prepared on the same platform using Virtual Reality Modeling Language (VRML). Later, it became evident that the ISIS animation features were extremely programming intensive, and the decision was made to limit ISIS its present GUI capabilities. The main problem with using Java on the IRIX platform was the relatively poor state of Java version 1.0 on this platform. In short, ISIS was extremely unstable under Java v. 1.0, but became quite stable at the moment it was launched under Java v. 1.1.

Overall, however, the project was successful in terms of delivering the software which automated administration of the design project. In spite of the drawbacks of programming in Java on the IRIX platform, the result was a platform-independent software package that tested well on UNIX (IRIX), Linux, Windows, and Macintosh workstations.

III. ISIS Application in a Senior-Level Design Course

ISIS has been used to administer a UCLA senior-level civil engineering design project five times during the period spanning 1999-2003. The typical class size is 20 students. The project has thus far been delivered to groups of three or four students acting as a team.

In spring of 1999, ISIS was "beta" tested and found to be highly unstable, for reasons mentioned above. By the winter of 2000, ISIS was fully functional with the exception of the cost-tracking module, which was undergoing its final round of debugging. This was the first time ISIS was employed to independently administer their design project.

In the initial offering of ISIS, and all subsequent offerings, access to the software was controlled—student groups exercised ISIS in a computer lab for two two-hour sessions each week for four to five weeks. After some last-minute debugging during the first week, ISIS performed consistently throughout the project. An ISIS user survey was used to summarize the students' impression of the software and its content. The one clear problem perceived by the students was the restricted access. They would prefer to use ISIS on their own time or to be able to login to ISIS from remote locations, such as their dorms. Otherwise, most perceptions were positive, as suggested by the following observations:

- The students perceived the ISIS software as user-friendly and engaging.
- They found the project meaningful and did not believe that animation would greatly add to the experience.
- ISIS relieved the instructor and TA of most of the paperwork associated with the project, and freed them to interact with the students on the project content (Harmon et al., 2002).

IV. Educational Assessment Efforts

We used modern assessment techniques to evaluate changes in student knowledge, teamwork skills, and attitudes toward ISIS (Chung et al., 2001). Such techniques are vital to achieving meaningful evaluations of instructional techniques, and clearly consistent with recent calls to use methods beyond course evaluations and student attitude surveys (ABET, 2000; ASEE, 1996, 1998; Waters and McCracken, 1997). This study was among the few to use a performance assessment to measure student learning in an upper division engineering course.

A pilot assessment was undertaken in winter 1999 to clarify our educational objectives and testing protocols. The ISIS software was relatively incomplete and failed on numerous occasions during this offering of the course, and hence, a full-scale assessment was not possible. The pilot assessment results were used to refine survey items and the content of the constructed knowledge map test employed in the main study.

The main ISIS assessment study was undertaken in winter 2000. The study included a combination of student surveys and the use of the Center for Research on Evaluation, Standards, and Student Testing (CRESST) knowledge/concept mapping system (see Osmundson et al., 1999). Details on the methods employed are provided elsewhere (Chung et al., 2001). Briefly, the student survey was used to collect data on student demographics, experience with complex projects (in school or at work), frequency with which they use general problem-solving skills, perceptions about ISIS and impressions about availability of ISIS resources. The self-regulation survey targeted information about students' self-perceived use of their own self-regulation skills (e.g., planning, self-checking, etc.). The concept mapping was used as a vehicle to measure course content understanding.

Table 2. Design of the Main ISIS Assessment Study

Occasion and tasks		
Week 1	**Weeks 2-3**	**Week 4**
(a) Regular classroom lectures	(a) Regular classroom lectures	(a) Regular classroom lectures
(b) Pre-ISIS constructed knowledge maps, 20-minute, on-line, controlled environment	(b) ISIS 12 hrs (5-6 sessions)	(b) Post-ISIS constructed knowledge maps, 20-minutes, on-line, controlled environment
(c) Pre-ISIS student survey (52-item)		
(d) Pre-ISIS Self-regulation survey (32-item)		

To address the issue of ISIS impact on students' learning, we draw on the results of students' pretest and posttest knowledge mapping performance and self-regulation survey. We focus on the relationship between performance on the knowledge map task and final grade, the extent to which students' content understanding improved from the pretest to the posttest, the quality of students' understanding, and the relationship between students' self-regulation and students' content understanding.

In terms of learning, the students tested appear to have profited from the ISIS project. The data from the main study are consistent with the idea that students gained deep content knowledge between the pretest and posttest. There were more deeply knowledgeable than shallow propositions in the knowledge maps and there was more use of propositions with theoretical relations. Students who reported higher use of self-checking cognitive processes also had higher course grades, fewer misconceptions, and fewer shallow propositions in their knowledge maps. Finally, students reported that they considered the ISIS activity as being generally effective in improving their skills in dealing with complex projects, linking theory to real-world applications, improving their problem solving performance, and developing positive attitudes toward ISIS.

There were several factors that limited the findings of the educational assessment, including:

- the small number of students tested;
- the lack of a control group; and
- the incompleteness of the expert map in the constructed knowledge mapping tests.

The number of students tested can best be changed through dissemination of ISIS to other instructors. This will provide the added benefit of testing the utility of ISIS in the context of different course content.

As noted by Chung et al. (2001), the lack of a control group was probably the most severe limitation of the assessment. Because of the typical enrollment in this upper division course, there are generally not enough participants to form non-ISIS control groups. Furthermore, as mentioned above, the time and effort expended to administer the design project manually is considerable. Given the lack of a control group, the extent to which the assessment findings are related solely to ISIS is unclear, particularly the observed gains in learning and differences in teamwork processes.

The incompleteness of the expert map used to judge the student constructed knowledge maps was probably of secondary importance (Chung et al., 2001). After the instructor reviewed all the propositions generated across all student maps, he reported that the expert knowledge map was incomplete. That is, some students created propositions that were appropriate and of high quality but excluded from the expert map. The major impact of this situation is in the "content score" measure, which we assume underestimated students' performance. Fortunately, the use of a scoring system for individual propositions in the knowledge maps could be used to rectify the problem of the incomplete expert map (students were awarded points for all meaningful propositions). Regardless, it would seem useful and plausible to form a workgroup of some type that would insure better coverage by the expert map in this type of an assessment.

V. ISIS Dissemination

The author led an ISIS workshop at the Association of Environmental Engineering and Science Professors Teaching and Research Symposium held at the University of Toronto in August 2002. ISIS CDROMs and users manuals were distributed to 12 potential users. In the fall of 2002, at least one of these instructors employed ISIS in his class at the University of Wisconsin at Platteville.

VI. Future Directions for ISIS

There are many limitations to our findings regarding ISIS and its educational assessment. Each of these limitations represents an opportunity for future work. With respect to the content and functionality of ISIS:

- An Internet-driven version of ISIS would (1) greatly facilitate maintenance and updating of the software, (2) create a platform for cyber-teams of students from different universities and disciplines, and (3) enable instructors from different disciplines to provide feedback on student work product in their area of expertise.

- Coordination of an ISIS workgroup could result in a large library of subsurface contamination scenarios to the benefit of instructors using the software year after year.

With respect to educational assessment:

- We used concept mapping and detected differences in the students' performance over the course of ISIS, which point to instructional sensitivity of the measure. We were among the first to try concept maps for this level of course, and we did so with a relatively small group. Thus, more work is needed to validate the use of knowledge mapping to measure students' understanding of complex subject matter, particularly when students are advanced (e.g., upper division students). Achieving greater evaluation numbers will be facilitated if more groups begin to use ISIS collaboratively, as discussed above.

- The ISIS project and accompanying assessment have only "scratched the surface" when it comes to the opportunities offered by education simulations and the tools need to evaluate their merit. Clearly, a broader range of assessments to measure cognitive outcomes are needed to conclusively address the EC2000 criteria. Assessments of problem solving, teamwork, design skills, lifelong learning, and communication are needed, and we believe they can be embedded within the simulation environment.

Acknowledgments

The author gratefully acknowledges the support of the National Science Foundation Combined Research-Curriculum Development Program, Award No. EEC-9700753 (Mary Poats, Director), the patient perseverance of UCLA's C&EE 164 class members and teaching assistants (Brian Dela Barre, Glenn Burks and Moises Carvalho), the educational assessment by Greg Chung and Eva Baker (both of CRESST), and the outstanding programming achievement by Jonathan Giron and Wilson Wong.

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