Int. J. Engng Ed. Vol. 18, No. 6, pp. 725–731, 2002
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Development and Formative Assessment of Web-Based Multimedia Labware for an Environmental Engineering Laboratory*

JAMES N. CRADDOCK and LIZETTE R. CHEVALIER
Department of Civil Engineering, Southern Illinois University, Carbondale, Illinois, USA.
E-mail: craddock@ce.siu.edu and cheval@engr.siu.edu

A web-based laboratory manual for an Environmental Engineering Laboratory is being developed. This paper presents an overview of the development and a summary of some formative assessment data collected during the initial phases of the project. The labware is intended to enhance student learning through the exposure to richer learning tools and advanced technologies by developing an interactive multimedia website for the laboratory, both before and after the actual experiment. For laboratories without the required equipment, the students can still investigate and link the theory, experimental methods, data collection, and analysis.

INTRODUCTION

MULTIMEDIA APPLICATIONS represent the best application of modern technology to education and training in all areas. It can be very cost effective and increase retention rates dramatically [1]. However, the good technical work being done to develop course-ware can lack an appreciation of the relationship between technology and education. The primary responsibility for what happens in learning must ultimately remain with professional educators [2]. Computer technology and multimedia applications are particularly relevant in engineering education [3–5]. The format is nonlinear, allowing the student to review certain parts in a manner that is much easier than with simple videotapes or audiocassettes. The effectiveness of computer-based instruction has been widely documented in numerous studies. These results are summarized in three survey papers [6–8].

In the Civil Engineering area, the development of a multimedia soils mechanics laboratories have been pursued [9–12]. Some work has also been done in the area of environmental engineering, including a look at some aspects of an introductory environmental lab [13, 14]. Other work in the area of environmental laboratories looks at an interactive multimedia lab manual [15, 16]. There has also been work done in the use of multimedia in a strength or mechanics of materials laboratory [17–20]

The Introduction to Environmental Engineering course is a junior level Civil Engineering course required for all civil engineering majors at Southern Illinois University Carbondale (SIUC). In addition, students from the environmental studies program may take this course. The laboratory component of the course includes topics such as measuring biochemical oxygen demand, determining suspended and settlable solids content, measuring the temperature, pH, and dissolved oxygen profiles in a lake, and conducting coliform bacteria tests.

The labware (laboratory courseware) is designed to present elements of theory, experimental procedure, data collection, data reduction, report writing and statistics. To accomplish this, the labware will combine text, illustrations, photographs, video-clips, sound, simulations, animations, hypertext descriptions, and hot-links to the Internet, making it truly multimedia. The final product will be published on a CD-ROM, with portions of the material and updates available on the World Wide Web. This format provides the opportunity for incorporating many novel aspects into the labware. The long-term goal of the project is to use the style and approach developed on this project as a template for other civil engineering laboratory courses. Common elements to all of these laboratories include modules on laboratory safety, report writing, statistics and unit conversions. The material for the web-based environmental engineering laboratory manual can be viewed at http://civil.engr.siu.edu/nsflab/Manuals/Main_Environmental.htm.

The labware has potential use in a diverse range of university environments. The pedagogy promoted by our approach is to engage students in active learning, and to accommodate various learning styles. By focusing on the development of an interactive multimedia program for the laboratory component of the course, the labware can strengthen the important bridge between application and classroom theory. For laboratories

* Accepted 5 June 2002.

equipped with the appropriate equipment, the labware is designed with the expectation that students review various aspects of the CD at different stages of the learning process. Students are expected to review the basic concepts of the associated theory and to experience a 'virtual laboratory' prior to their actual hands-on experience. For laboratories that do not have access to state-of-the-art equipment, the students may still investigate and link the theory, experimental methods, and data collection.

PROJECT OBJECTIVES AND GOALS

As previously stated, the overall objective of this project is to prepare develop an interactive multimedia based laboratory manual (labware), with a professional design for the Introduction to Environmental Engineering class, using improved features possible from with technology, including, videos, interactive modules, and access to digital data.

One of the goals of this effort is to enhance student learning in these laboratory classes by use of this labware. The results of this project are meant to accomplish several things. By the use of modern technology, it is planned that printed lab manuals will be replaced. The educational goals of this project include providing modern interactive instruction, increasing student interest in these classes, and enhancing the overall laboratory experience. Furthermore, the students' use of statistics in understanding and interpreting experimentally obtained data will be expanded. By the multimedia nature of this work, the use and acceptance of computer technology in civil engineering curricula will be increased and improved.

A secondary benefit of this work is that it provides a training module for graduate teaching assistants, providing additional enhancement to the laboratory experience. Due to the nature of gaduate studies, the teching assistants only teach the lab for two or three semesters. There is a recurring need to train new lab assistants. The graduate student has usually done the experiment as an undergraduate. However, their recollections of the details diminish with time. New equipment may have been introduced. There is a need to reinforce their knowledge of how to do the experiment. Informal discussions with graduate students has emphasized the usefullness of the website and the related video clips for their personal review of the material, helping them better prepare to conduct the lab.

In a broader sense, it is planned that this material will be disseminated to a large and diverse group of colleges and universities. The quality and effectiveness of this work should serve as a model to encourage others to develop similar products for other laboratories. In certain situations, it will serve as 'virtual lab experience' for institutions that do not have one or more of the experiments available at their locations.

PROGRAM OVERVIEW

Working with the College of Mass Communication and Media Arts Interactive Multimedia Program provides a unique opportunity for the College of Engineering. Elements of design and state-of-the-art web and CD-based technology are integrated into the project without the daunting task of mastering advanced software and hardware. In return, the project provides a client base for graduate students from the Interactive Multimedia Program within the academic environment. The main software used includes Macromedia's Dreamweaverfor web development, and Adobe's Premiere for video editing and Adobe's Photoshop for still photography. The video has been recorded with a digital camcorder using the Mini DV format tapes.

The website features an opening page. From there, one navigates to the main page for the site. Currently, this page has links to the environmental labs, the strength of materials lab, and general topics such as lab safety, report writing, and statistics. Additional links for the soil mechanics lab, the fluid mechanics lab, and the construction materials lab are also provided. It is planned to develop those sites later. The main pages for the existing laboratories have similar format, style and navigation.

A portion of the main page for environmental engineering is shown in Fig. 1. On this page, an overview of the profession as well as an introduction to standard methods used in regulated facilities is presented. From this page, one can navigate to the other classes by clicking on the list of topics in the top line of the page. The individual labs for the environmental class are listed below the picture heading near the top of the page. Each lab has the typical elements of introduction, procedure, equipment, analysis, references, and sample data sheets. Links to these topics are provided along the left

Fig. 1. Main page for the environmental laboratory site.

Fig. 2. A still shot from a digital video clip showing the procedure for coliform testing..

side of the page.What makes this site unique is the integration of short digital video clips and sample data. For example, in the solids lab, the introduction includes a video clip that explains the application of the lab in the real world. It shows an effluent discharge point of a wastewater treatment facility into a receiving body of water. Additional video clips are found throughout the procedure section. Here, the objective of each video is to show the students the equipment used as well as the proper use of the equipment. A sample still shot from the coliform lab video is shown in Fig. 2. The shorter video clips have the additional advantage of shorter download times.

In addition to the video clips, many of the labs have additional data sets. These data sets have utility in statistical analysis and virtual labs. For the lake profile lab, historical data is included that allows the student to see the lake turnover from temperature, dissolved oxygen and pH data. Examples of data reduction and analysis are also provided from sample data in several experiments. In some cases, this includes a downloadable Excel file which the student can use as a template.

ASSESSMENT

During the first semester, the basic lab manual was on-line. By the second semester, a professional website design was employed with quality photographs. In addition, digital videos were posted for four of the environmental engineering laboratories. In the introduction of these labs, a video clip is used to show the use of the lab in the real world.

The website was introduced in five experiments during the first semester of the project:

- measuring biochemical oxygen demand;
- determining solids content;
- measuring the temperature and dissolved oxygen profiles in a lake;
- evaluating solid waste characteristics;
- conducting coliform bacteria tests.

The formative assessment of the site was based on a questionnaire presented on a six-point scale, where scores of 1, 2 or 3 were used to indicate that the students strongly agreed, agreed, or slightly agreed with the statement. Scores of 4, 5, or 6, indicated that the respondent slightly disagreed, disagreed or strongly disagreed with the statement.

The following questions were used on the survey:

1. The information presented on the website was complete, clear and effective.
2. The website is more effective than printed lab manuals.
3. The level of detail on the website for this experiment was appropriate.
4. For this experiment, the website needs more detail.
5. For this experiment, the website needs less detail.
6. Video-clips, sound clips and photographs would help me understand this experiment better.
7. Reading the material on the website prior to conducting the experiment helped me understand and conduct the lab.
8. Reading the material on the web prior to conducting the experiment helped me with data reduction and interpretation of the results.
9. Reading the material on the website after conducting the experiment helped with data reduction and interpretation of the results.

Some questions relate to the development and overall quality of the web-based lab manual. These include questions 1, 3, 4, and 5. Questions 2, 6, 7, 8, and 9 relate more directly to the educational objectives of the project. The results are shown in Table 1. There were 24 respondents to the survey. The results presented are the percentage of respondents that agreed (i.e. answered 1, 2, or 3) or disagreed (i.e. answered 4, 5, or 6) with the statements. The students surveyed did not respond to all questions, however, the total number of students were still used to determine the percentages.

By the second semester of this project, the website design was integrated as well as quality photography. In addition, short video clips were added to four of the environmental engineering labs. Students enrolled in the course during this semester were asked the following about those four labs:

1. Compared to other websites for engineering education, the artistic design and the layout of the website is well done (appealing).

Table 1. Summary of Survey Responses for the First Semester

Question	BOD		Lake Profile		Solids		Solid Waste		Coliform		Overall	
	Agree (%)	Disagree (%)	Agree (%)	Disagree (%)	Agree (%)	Disagree (%)	Agree (%)	Disagree (%)	Agree (%)	Disagree (%)	Agree (%)	Disagree (%)
1	73	27	95	5	92	8	96	4	100	0	91	9
2	47	53	89	11	64	36	67	33	56	44	65	35
3	87	13	100	0	92	8	96	4	92	8	93	7
4	40	60	58	42	60	40	33	67	44	56	47	53
5	33	67	47	53	48	52	21	79	36	64	37	63
6	87	13	79	21	84	16	63	38	88	12	80	20
7	80	20	100	0	80	20	67	4	90	10	83	10
8	90	10	100	0	70	30	50	8	90	10	80	11
9	92	8	88	13	83	17	79	0	88	12	86	10

2. Compared to websites in general, the artistic design and layout of the website is well done (appealing).
3. The website is easy to navigate.
4. The videos used in the introduction to the lab effectively show the application of the lab in engineering practice.
5. The amount of material covered in the videos is appropriate.
6. Compared to other videos on the web, the videos are of high quality.
7. The sample data with data reduction is helpful.
8. The additional data sets provided at the end of the lab are beneficial for study beyond the basic lab (i.e. statistical analysis, additional case studies.
9. The website is more effective than printed lab manuals.
10. I prefer a printed lab manual.
11. I prefer having both the website and the printed manual.
12. The level of detail on the website for this experiment was appropriate.
13. The material on the website should help students with data reduction and interpretation of the results.

Once again, some questions relate to the development and overall quality of the web-based lab manual. These include questions 1, 2, 3, 5, 6, and 12. Questions 4, 7, 8, and 13 relate more directly to the educational objectives of the project. Questions relating to the use of a web-based manual instead of a traditional manual include 9, 10, and 11. The results are shown in Table 2. There were fifteen respondents to the survey. As with the previous assessment, the survey was based on a six-point Likert scale.

By the third semester of this project, the website design was fairly complete, integrating quality photography and short video clips for most of the environmental engineering labs. Students enrolled in the course during this semester were asked the following:

1. Videos were used effectively to show me the application of this lab in engineering practice.
2. Videos were used effectively to show me the procedures used in conducting the experiment.
3. The text, photographs, illustrations and/or other multimedia elements were effective in showing me the necessary procedures used in conducting the experiment.
4. The additional data sets provided at the end of the lab are beneficial for study beyond the basic lab (i.e. statistical analysis, additional cases studies).
5. The overall level of detail on the website for this experiment was appropriate.

Table 2. Summary of Survey Responses for the Second Semester

Question	BOD		Solids		Lake		Coliform		Overall	
	Agree (%)	Disagree (%)	Agree (%)	Disagree (%)	Agree (%)	Disagree (%)	Agree (%)	Disagree (%)	Agree (%)	Disagree (%)
1	95	5	95	5	100	0	100	0	98	3
2	95	5	95	5	92	8	92	8	94	7
3	80	20	80	20	100	0	100	0	90	10
4	95	5	95	5	100	0	100	0	98	3
5	89	11	83	17	100	0	100	0	93	7
6	89	11	89	11	100	0	100	0	95	6
7	89	11	90	10	100	0	100	0	95	5
8	83	17	89	11	100	0	92	8	91	9
9	72	28	65	35	77	23	85	15	75	25
10	67	33	60	40	54	46	69	31	63	38
11	89	11	80	20	69	31	69	31	77	23
12	90	10	90	10	100	0	100	0	95	5
13	95	5	94	6	100	0	100	0	97	3

6. I found the use of multimedia elements in a laboratory manual to be helpful.
7. I am better prepared for the class with a web based lab manual than I would be using a traditional printed lab manual.
8. I learn more when material is presented in this way.
9. I think that the multimedia lab manual presented in this website is an improvement over traditional printed lab manuals.
10. I would prefer having both the website and some supplementary printed material.

Now some questions (one through five) relate to the website concept and some (six through ten) to the overall concept and educational goals. Responses for only one lab were solicited this semester. There were six respondents to the survey. Even though this is a small sample size, the results are shown in Table 3. As with the previous assessment, the survey was based on a six-point Likert scale.

In addition, a section on the survey for comments was included this time. Some of these comments include:

- 'The web and traditional manuals work great together.'
- 'It's a step in the right direction. I feel technology should be used in classes.'
- 'I preferred the web-based manual over the traditional printed manual. I liked the Analysis portion the best because it clearly stated what needed to be in the Discussion/Conclusion section.'
- 'However, I did look at them (the video clips) at home and found them useful in understanding labs better.'
- 'The website was the best lab manual I have ever used! I have been in about ten different labs and never fully understood what I would be doing in the labs beforehand. This website allows you to visualize what you will be doing and helps to better understand the material.'
- 'I really liked the whole website.'

Table 3. Summary of Survey Responses for the Third Semester

Question	BOD	
	Agree (%)	Disagree (%)
1	83%	17%
2	83%	17%
3	83%	17%
4	100%	0%
5	83%	17%
6	83%	17%
7	67%	33%
8	83%	17%
9	100%	0%
10	33%	67%

ANALYSIS AND CONCLUSIONS

In the first semester surveys, questions 4 and 5 were intended to monitor student response by posing a question in reverse. In this case, the students were asked whether the website needs more detail, then whether the website needs less detail. Overall, a majority of students disagreed with both statements (53% and 63%). This suggests that the students found the level of detail to be appropriate. In fact, these two questions received the highest disagree ratings, with the next highest disagreement being 35% disagreeing with question 2, which compares the website to printed manuals.Overall, there was a positive response to the use of the labware, even at this preliminary stage. Since video clips, animation and photography were not available to students at this point; the negative response to question 2 was anticipated. Without these elements, the website or CD offers little or no advantages to the traditional hardcopy manual students can take to the lab, since the hardcopy manual allows for in-class note-taking, reference and data entry. This conclusion was in part drawn from informal discussions with the students. In response to the this assessment, PDF files of the experiments were subsequently made available for the students to download and print. As with other elements of this project, this tries to accomodate individual learning styles and preferences.

In the second semester, there is strong evidence of the quality and effectiveness in elements ranging from design and navigation of the site to the benefits of the videos and data analysis. With the addition of the video clips and photography, an average of 75% of the students indicated that the website is more effective than printed lab manuals. In addition, 98% of the students indicated that the introductory videos, which demonstrate the application of the lab in the field as opposed to experimental procedure, were effective.

In the third semester, there was almost universal approval of the concept and content of the website. The very positive comments of the students reflect the survey results. All respondents agreed that multimedia lab manual presented in the website was an improvement over traditional printed lab manuals. Positive responses to this question were 65%c and 85% in the first and second semester surveys. Although the results are based on small sample sizes, these results indicate that the concept of a web-based lab manual is very popular with the students. Also, the acceptance of the concept is increasing as the website matures and has more multimedia features.

The responses about the use of a printed manual instead of or in addition to the web-based manual are interesting. In the second semester results 75% of the students said the considered the web-based manual to be superior to a printed manual. However, 63% said they would prefer to have a printed manual and 77% said they would like to have both. This indicates that there may exist a

cultural resistance to not having a hard copy of the lab manual available. Even though students found the new web-based manual to be superior, they were still more comfortable with the traditional printed manual. This trend seems to have reversed in the third semester results, as only 33% indicated that they would still like to have a printed manual.

In all three semesters, there is a consistently positive reaction to the presence of sample data sets. The positive responses range from 86% to 100%. This indicates that the sample data sets are one of the strongest elements of the labware. The use of the video clips is another popular feature of the labware.

One somewhat disappointing results is the response to the question in the third semester survey about being better prepared for the lab. There was a positive response of 83% to the idea that the student would learn more when the material is presented on the web. However, the response to the question about being better prepared for the lab had a 67% positive result. Again, it is hard to make any definite conclusions based on the small sample size, but these numbers seem to indicate that even though it appears that this approach enhances student learning, that it still requires some preparation time that not all students are willing to invest.

The first part of a multimedia project to develop a lab manual for environmental engineering has primarily focused on the design of the project and the production of video clips. The second stage of the work included the addition of several new labs and multimedia elements. As more features are added to the labware it is becoming much more popular. This is illustrated both by the survey results and by student comments. Students' responses show that this approach is indeed meeting the project goals of enhancing student learning and increasing student interest in the class. It does appear that this project is enhancing the overall laboratory experience. Despite some initial resistance on the part of some students, it does semm that .replacing the printed lab manuals traditionally used will be accepted by and helpful to the students.By the multimedia nature of this work, the use and acceptance of computer technology in civil engineering curricula is being increased and improved. It should also be pointed out that the assessment process itself is coninually evolving as the project moved from it initial phases to a more final format.

The lab manual for environmental engineering is being developed concurrently with a lab manual for strength of materials. The total cost of the project has been about $300,000. However, this included about $100,000 for new equipment for the environmental and mechanics of material laboratories. In addition, about $25,000 was spent on software and multimedia equipment (computers, cameras, scanners, etc.). No actual figures are available on the impact the project has had on retention, but anecdotal evidence suggests that the project has been beneficial.

The authors encourage the use and feedback of the website for environmental engineering laboratory manual at http://civil.engr.siu.edu/nsflab/Manuals/Main_Environmental.htm.

Acknowledgment—This project is funded in part from the National Science Foundation (DUE—CCLI Project Number 9952577), the College of Engineering at Southern Illinois University Carbondale (SIUC), the Department of Civil Engineering at SIUC, and the College of Mass Communication and Media Arts at SIUC. The authors would like to thank Dayne Morris, Alison Arndt, Kudzai Musumhi and Craig Irwin for their invaluable contributions to the project.

REFERENCES

1. Iskander, M. F., Catten, J. C., Jones, A., Jameson, R., and Balcells, A., Interactive multimedia lessons for education, *Proc. American Society for Engineering Education Annual Conference*, Washington D.C., June 23–26, 1996.
2. Holes, W. Neville, The myth of the educational computer, *IEEE Computer Magazine*, **32**(9), 1999, pp. 36–42
3. Green, R. A., and Huddleston, D. H., Changing the engineering undergraduate experience by appropriate use of computer technology, *ASEE/IEEE Frontiers in Education Conference*, Tempe, AZ, November 4–7, 1998
4. Chin, R. A., and Frank, A. R., The multimedia instruction initiative: implications for engineering education, *Proc. American Society for Engineering Education Annual Conference*, Washington D.C., June 23–26, 1996.
5. Mutharasan, R., Magee, W., Wheatley, M., and Lee, Y., Multimedia assisted instruction in upper level engineering courses, *Frontiers in Education Conference*, Pittsburgh, PA, November 5–8, 1997.
6. Niemicec, R., and Walberg, H., Comparative effects of computer-Assisted Instruction: A Synthesis of Reviews, *J. Educational Research*, **3**(1), 1987, pp 19–37.
7. Kulik C-L., and Kulik, J., Effectiveness of computer-based instruction: an updated analysis, Computers in Human Behavior, **7**, 1991, pp. 19–37.
8. Aleni, Morteza, and Barnes, Robert, A multimedia soil mechanics laboratory software development for teaching and learning purposes, *Proc. Int. Conf. Engineering Education*, Ostrava, Czech Republic, August 10–12, 1999.
9. Masala, Srloljub, Biggar, Kevin, and Geissler, Colin The geotechnical virtual laboratory, *Proc. Ann. Conf. Amer. Soc. Engineering Education*, St. Louis, MO, June 18–21, 2000.
10. Budhu, Muniram, A multimedia geotechnical laboratory test courseware, *Proc. Ann. Conf. Amer. Soc. Engineering Education*, St. Louis, MO, June 18–21, 2000.

11. Budhu, Muniram, An interactive virtual geotechnical laboratory, *Proc. Ann. Conf. Amer. Soc. Engineering Education*, Albuquerque, NM, June 24–27, 2001.
12. Hart, H., and Kinnas, S. A., Developing web-based tools for environmental courses, *Proc. Ann. Conf. Amer. Soc. Engineering Education*, Seattle, WA, June 28–July 1, 1998.
13. Robinson, R. B., Multimedia tour of a wastewater treatment plant, *Proc. Ann. Conf. Amer. Soc. Engineering Education*, Seattle, WA, June 28—July 1, 1998.
14. Katz, L. E., Weather, L. J., Kozlowski, R., Scott, M. and Manion, W., A multimedia based laboratory course for environmental engineering, *Proc. Ann. Conf. Amer. Soc. Engineering Education*, Seattle, WA, June 28–July 1, 1998.
15. Chevalier, L. R. and Craddock, J. N., Interactive multimedia labware for civil engineering curricula, *Proc. Ann. Conf. Amer. Soc. Engineering Education*, Albuquerque, NM, June 24–27, 2001.
16. Chevalier, L. R., and Craddock, J. N., Formative assessment of interactive multimedia labware for environmental engineering laboratory, *Proc. Int. Conf. Engineering Education*, Oslo Norway, August 6–10, 2001.
17. Craddock, J. N., and Chevalier, Lizette R., Web based laboratory manuals in civil engineering, *Proc. Int. Conf. Engineering Education*, Taipei Taiwan, August 14–16, 2000.
18. Rais-Rohani, Masoud, and Brown, Debbie T., Development of a virtual laboratory for the study of mechanics, *Proc. Ann. Conf. Amer. Soc. Engineering Education*, St. Louis, MO, June 18–21, 2000.
19. Craddock, J. N., and Chevalier, Lizette R., Interactive multimedia labware for a torsion experiment, *Proc. Ann. Conf. Amer. Soc. Engineering Education*, St. Louis, MO, June 18–21, 2000.
20. Chevalier, L. R., Craddock, J. N, Riley, P. C., and Trunk, B. J., Interactive multimedia labware for strength of materials laboratory, *Computer Applications in Engineering Education*, V8.

James Craddock received his BS, MS, and Ph.D. degrees in Aeronautical and Astronautical Engineering from the University of Illinois. He joined the faculty at Southern Illinois University—Carbondale in 1980. His main interest is solid mechanics with an emphasis on composite materials and the finite element method. He is also active in innovative engineering education methods using the Internet and multimedia.

Lizette Chevalier received her BS degree in Civil Engineering from Wayne State University, and her MS and Ph.D. from Michigan State University. She joined the faculty at Southern Illinois University—Carbondale in 1995. Her main interest is environmental engineering with an emphasis on soil remediation involving nonaqueous phase liquids. In addition, she is active in engineering education using modern technology.