Instructing Courses With Mathematical Content Via the Web and Computers

Glen Smerage
University of Florida

Introduction

Engineering courses involve mathematics in presentations of theory and skills, demonstrations, exercises, and work by which student learning is evaluated. The Web, a personal computer, and mathematical software are excellent means for incorporating mathematics into courses. During the past four years, the author has developed and applied approaches to employing those means in courses with significant mathematical content. A Web based system for course delivery has emerged with the following major components: electronic knowledgebase, computerized problems, exercises, and solutions, a Web site, and a learning studio. The system has been employed successfully in five semester presentations of a course on biological systems analysis at the University of Florida and at Florida Agricultural and Mechanical University. It is now being applied to a new course on quantification of biological processes. The system, illustrations from the biological systems analysis course, and experiences of the author are presented in this paper.

Knowledgebase

Knowledgebases (textbooks) need not be electronic, and some people find curling up in a chair or on a couch with a computer unappealing. Nevertheless, the author believes electronic media are attractive and effective for knowledgebases. Electronic knowledgebases may be used for learning, lecturing, and reference with several advantages over printed knowledgebases.

One advantage is the parallel, rather than serial, architecture available in electronic documents via hyperlinks. Elective movement about a well linked knowledgebase is efficient and effective for the user, and parallel writing is richer in diversity and potentially communicates more effectively and efficiently than the printed page. Another advantage is the opportunity for active and better communication and demonstration of concepts and skills via animation, simulation, live demonstration, and video. Authors may more easily alter and expand existing components of a knowledgebase and add new components without incurring problems in the format of the whole document. Passive verbal and mathematical texts and graphics are readily created via word processing, equation editor, and graphical softwares. Active presentations require other softwares and considerations.

Mathematically, an electronic knowledgebase may contain active as well as passive components. The passive mathematical text common in engineering knowledgebases is readily composed via the equation editor in the word processor used to compose passive verbal text. Active mathematical components may be accomplished via commercial mathematical software; of several products available, the author chose Mathcad[3] as most suitable to his writing, mathematical, and instructional styles. Active components provide students interactive, exploratory learning through changing parameters and conditions of analyses and performing simulations. Interaction and exploration promote interest and insight, enliven learning, and add breadth, diversity, and strength to learning experiences in comparison to passive, printed knowledgebases. Graphical output available in mathematical software further strengthens the quality of active mathematical components and the learning process.

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An author composes an electronic knowledgebase by using a word processor with an equation editor for passive verbal and mathematical text components and suitable software for passive graphical entities. Graphics are either embedded in text components or saved as discrete graphical components. All passive verbal, mathematical, and graphical components are saved in the Portable Document Format (pdf) using Acrobat[1] for preservation of mathematical symbols and across platform standardization of format. The pdf is used rather than html format because of the mathematics. Active mathematical components are composed in Mathcad and saved as discrete Mathcad files. Examples in a knowledgebase are composed as passive pdf files or active Mathcad files. Demonstrations are composed as active Mathcad or animation files. Hyperlinks are placed in the pdf text files to integrate all passive and active components of a knowledgebase; they are implemented in Acrobat. The resulting knowledgebase has hierarchical structure that may be written with all components limited in substantive scope and size and with depth of coverage of any topic accomplished through elaborating hyperlinks. The Web site is the preferred means for distributing a knowledgebase, but CD-ROM is an alternative. A knowledgebase is downloaded from a Web site via a browser configured to display received files in the appropriate application; e.g., pdf files in Acrobat Reader[2] in the browser window and Mathcad files in a Mathcad window outside the browser.

The author has developed a knowledgebase using the methods discussed above for a course on biological systems analysis; it may be used anywhere a computer with Internet connection and browser, Acrobat Reader[2], and Mathcad[3] is available. The reader may observe the compositional methods by exploring that knowledgebase on the Web at the following URL:

http://www.agen.ufl.edu/~smerage/ABE5643/Book/Bk00001.pdf

Exercises and Problems

Exercises facilitating understanding and learning of topics and skills in a course and problems for evaluating student learning are standard practices in engineering courses, and they typically involve substantial mathematics. The author has found that students may work all exercises and problems in mathematical software such as Mathcad[3] with significant benefit and without sacrificing learning and development of ability to think. Furthermore, the Web is an excellent vehicle for dissemination of exercise/problem statements and solutions and for two way transfer of student work between students and instructor.

The following system is very effective. A set of problem statements, each of which may be used as an example, exercise, or problem for student evaluation, is developed in the chosen mathematical software, with each statement saved in a distinct file. Solutions are added to renamed, duplicates of the statement files, fully utilizing mathematical, graphical, and annotational facilities of the software. Separate folders of problem statements and solutions are placed on the Web site for a course, and a corresponding html index of files is added to each folder. Selection of a link in an index causes an Internet browser configured to use the mathematical software to download the selected file into that software. A student or instructor may then develop a solution within a retrieved statement file; an instructor may discuss or a student may study a retrieved solution file. A student sends to the instructor as e-mail attachments files of problems worked for evaluation. The files are evaluated and annotated by the instructor within the mathematical software, assigned a grade, saved, and returned by e-mail attachment.

A few hundred problems have been developed for the biological systems analysis course. The reader may examine via Mathcad[3] statements for those problems by selecting links in the Index of Problems at the following URL:

http://www.agen.ufl.edu/~smerage/ABE5643/Problems/

Problem solutions may be examine via Mathcad^3 by selecting links in the Index of Problem Solutions at the URL:

http://www.agen.ufl.edu/~smerage/ABE5643/ProbSols/

Learning Studio

Active learning in courses involving mathematics may be pursued in and outside a classroom by requiring students to study the knowledgebase and work exercises and problems at a computer. Access to those materials and general information about a course via the Web is preferred; CD-ROM is an alternative source. Students are required to study the knowledgebase outside classroom sessions in preparation for classroom activities. Classes are conducted in a room of networked computers with Internet access, referred to as a learning studio. In the studio, the instructor presents overviews of current topics, examples, and demonstrations; students work exercises with guidance from the instructor and reference to the knowledgebase; and discussions are conducted. Students observe activities at the instructor's computer on their monitors via remote control software. That software also may be used by the instructor to observe and interact with individual students as they work at their computers. Alternatively, the instructor interacts by walking about the studio. After students have worked an exercise sufficiently, the instructor's solution is presented and discussed. Several exercises are worked and discussed during a studio session.

The Complete System

A Web site completes the preferred delivery system for a course involving substantial mathematical content. The site contains a home page for the course with links to other html pages presenting: course syllabus; general information about a course; schedules for assigned knowledgebase study; suggested exercises outside studio sessions, and problems to be solved for evaluation; and other types of important information. The home page must contain links to the knowledgebase, indices of problem statements and solutions, instructions on using Mathcad^3, and e-mail to the instructor.

The reader may explore the home page for the course on biological systems analysis at the URL:

http://www.agen.ufl.edu/~smerage/ABE5643/GInfo.html

Application and Results

The author developed the system described above for Web delivery of courses involving mathematics and the knowledgebase and problem statements/solutions for the biological systems analysis course during the past four years. To date, the Web delivery system has been applied to the biological systems analysis course in three semesters at the University of Florida and two semesters at Florida Agricultural and Mechanical University. That will continue at both universities for the foreseeable future. The system also will be employed in the development and operation of a new course at the University of Florida on quantification of biological processes.

The first semesters of web delivery of biological systems analysis at both Universities were encouraging but difficult due to technical problems with computers, software, and networks. Delivery in successive semesters improved greatly and demonstrated strongly the values of active learning, learning studio, electronic knowledgebase, Web delivery of a course involving mathematics, and the particular system developed. Web delivery of the systems analysis course at both universities now is very trouble free, efficient, and instructionally effective. The only exception to that statement pertains to the remote control software. At both universities and in learning

studios of ten computers, the remote control software has not functioned well or reliably for student viewing of the instructor's computer and instructor viewing of student computers. Improvement in that software will be necessary before that feature of a learning studio may be realized. Operation of the course at FAMU is partially a form of distance education. A next step would be to deliver to deliver that course or another with mathematics via the Web in a true distance education venue. In that case, well working remote control or conferencing software would be very important.

Student responses are quite positive to the knowledgebase content and structure, to the problems and working them in Mathcad[3], to working and discussing exercises during class sessions rather than passively listening to lectures, to transfer of their work by e-mail attachment, to Web access to course materials and e-mail access to the instructor, and to doing all facets of the course at a computer. There is general student agreement that active study and learning activities promote stronger learning of both subject matter and skills and that development of computer skills will be important to future occupational work. However, there have been a relatively few students who preferred to work problems via pen and paper and/or study hardcopy of the knowledgebase. The latter has been especially true for students whose Web access to the knowledgebase was slow due to slow computers/modems. Typing and computer skills necessary for efficient work have been beyond some student capabilities, but that is rapidly improving as more courses demand computer use.

The author believes that Web delivery and systems such as that described herein are productive, meaningful paths for courses involving substantial mathematics and for courses in general. With electronic media there are many more creative ways to present subject matter and skills, to explain, illustrate, demonstrate, and communicate, and to promote understanding and learning. The most recent offerings of the biological systems analysis course at UF and FAMU have demonstrated improved instruction by the author and learning by the students. The development process and initial operations of the delivery system and course materials were troubled and at times frustrating, but the efforts are now bearing fruit, and newcomers to Web delivery of courses with mathematical content should have easier tasks by learning from their predecessors. Composing knowledgebases and sets of mathematical problems and solutions for Web delivery will require much time and effort, but so also will composing a good, passive textbook.

References

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   http://www.adobe.com/

2. Adobe Systems. Acrobat Reader. Mountain View, CA: Adobe Systems, Inc.
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GLEN SMERAGE
Glen Smerage is an Associate Professor in the Department of Agricultural and Biological Engineering at the University of Florida. His activities include research and teaching in biological systems analysis and development of instructional methods for engineering education.

NOTE: Knowledgebase, problem statements/solutions, and delivery system will be demonstrated.