Computer Based Learning for Engineering Mechanics:
"If we build it, will they come?"

Roger Toogood, Bill Lipsett, & Shelley Lorimer
Dept. of Mechanical Engineering

Terry Hrudey & Art Peterson
Dept. of Civil and Environmental Engineering

Stanley Varnhagen
Academic Technologies for Learning
University of Alberta

Abstract

This paper describes a series of Computer Based Learning (CBL) modules for courses in Engineering Mechanics (Statics, Dynamics of Particles, Rigid Body Dynamics). The format, content, and pedagogical approach is described. Student reaction and responses to the use of the modules is presented and discussed. Some lessons learned by the authors through the development and implementation of these modules are also presented.

Introduction

Universities throughout North America are looking for alternate modes of delivery of educational resources: asynchronous learning, distance education, WEB-based resources, and so on. In the next decade, there will be a tremendous change in the way courses are presented and in the resources required. Some observers have likened this evolution in education to that which followed the development of the printing press[1]. That evolution, however, occurred over several decades. The current evolution is marked by major developments occurring on a monthly basis.

One of the possible forms of the educational resources for the (near) future are stand-alone programs that are a primary learning resource for a course. Such CBL materials offer a number of advantages: self-paced, asynchronous learning, effective multimedia delivery, release of instructors to provide more personalized "service", and even possibly economic advantages [1].

This paper describes some CBL courseware for students entering programs in engineering. At the University of Alberta, the target courses (ENGG 130 Statics, ENPH 131 Particle Dynamics) are required of all first year engineering students, and registration in each course is typically over 500 students per year. The third target course (Mec.E. 250 Planar Rigid Body Dynamics) is

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[1] See the ASEE President's Letter in *PRISM*, October, 1997, p. 39.

required for mechanical and electrical engineering students in their second year (total enrollment of about 230 at the University of Alberta). It is important to note that the content of these courses is very stable from year to year and that similar subject matter is also presented in many programs across North America in engineering, general science, and applied mathematics. Thus, there is a potentially large user community for courseware of this type, which is then reflected in the larger effort that can be afforded on its development. For the present modules, this has required the efforts of five content experts, two educational technologists, a graphic designer, and a half dozen student programmers, with the effort spread out over three years.

From a learning standpoint, CBL means that students can proceed through the material at their own pace. These courses are typically presented to class or section sizes of 70 to 100 students who have diverse backgrounds and preferred learning styles. As might be expected, different students are able to absorb new material at different rates and in the large lecture-format classes, a significant proportion of a class is either bored or left behind. This considerably lowers the students' learning efficiency and interest. Self-paced learning allows students to proceed at the optimal rate of their own choosing. They are able to go back through the material again if they are having difficulty understanding the concepts. Course instructors, meanwhile, are freed from the lecture-mode delivery of routine material, and can devote more time to special cases and problems or to individual, one-on-one meetings with students. For very large multi-section courses, it may be possible to reduce the number of instructors. We emphatically do not advocate a total reliance on this software for course delivery, recognizing that significant learning occurs in a face-to-face environment or via other mechanisms. However, we suggest that a considerable portion of the routine lecture material and content can be presented more effectively and with higher comprehension rates for all students using self-paced instruction delivered via CBL. Although the modules are aimed at *primary delivery,* they can also be used as a course supplement for tutorial or review purposes.

Courseware Design and Pedagogical approach

Upon review of several available packages in this subject area (usually bundled as a supplement to a textbook), we were not satisfied with their approach to the learning environment or process. Most are basically an electronic textbook that allow the student to navigate through screens of information or run demonstrations and animations. Such programs are useful in developing visualization skills, however no teaching interaction with the student was involved and there was little or no corrective feedback to the student. As such, we feel that its effectiveness as a teaching tool for primary delivery or remediation was diminished. Thoughtful and reasoned action by the student is critical to the learning process, and this is further reinforced by interaction of the software providing appropriate feedback for the student's actions.

Each of the present modules contains the development of the theory and worked examples. The philosophy behind the modules is based on the saying:

"I hear and I forget.
I see and I remember.
*I do and I understand."*
                    - Confucius

To that end, the modules are highly interactive, requiring the student/user to input answers or perform other actions (described below) throughout the program. For all interactions, student responses are adjudicated and appropriate feedback is given. Although the student learner has full control over the program by means of a navigation system, program design is meant for top-down use, rather than using hypertext-like jumps from topic to topic. The typical sequence in a module involves an overview, motivational problem, development of theory, increasingly complex examples worked out with the student, and a summary.

The software is organized in self-contained stand-alone modules (see the Table below), each covering a major topic in one of the courses. Students typically take from one to three hours to complete a single module. The material in each module is organized in chapters, with each chapter broken down into pages. Each page can contain several sequential screens of information and interactions. The overall screen design and controls are indicated in Figure 1. The entire user interface utilizes graphical icons for quick recognition and ease of use. Tools available to the student/user are a built-in calculator, a clipboard for storing important results, and the facility to print out screens (including graphics) if an appropriate printer is attached.

Table I Target Courses and Related CBL Modules

Statics	Particle Dynamics	Planar Rigid Body Dynamics
Vectors	Vectors	Kinematics
Particle Equilibrium	Rectilinear Kinematics	Force and Acceleration
Force System Resultants	Planar Kinematics	Principal of Work and Energy
Equilibrium in Two Dimensions	Relative and Constrained Motion	Principal of Impulse and Momentum
Structural Analysis	Newton's Laws	Simple Vibrating Systems
Internal Forces	Work and Energy Methods	
Friction	Impulse and Momentum Methods (Single Particle)	
Center of Gravity and Centroid	Impulse and Momentum Methods (Systems of Particles)	
Moments of Inertia		

The CBL software is written using *Authorware Professional* [2], and is packaged to run under Windows 3.x, Windows 95, Windows NT, or Macintosh. Two delivery modes are currently used: over the Internet and installation on a local network within a classroom or lab. Software installation is straight forward - downloading and installing a module from the Web is entirely automated, using *InstallShield* and *InstallFromTheWeb* [3].
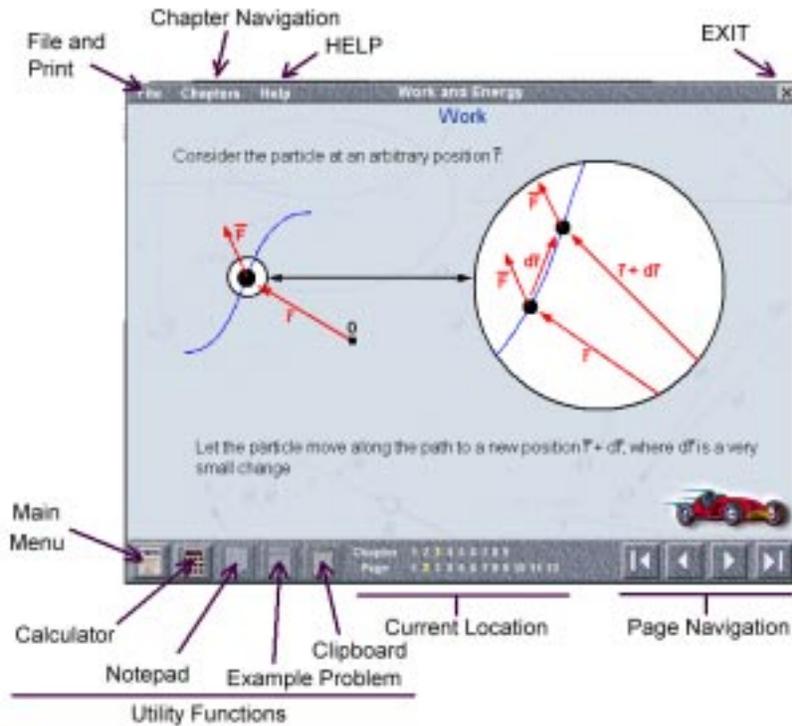

Figure 1 Layout of screen elements and controls

The modules are highly interactive so that student users cannot be passive learners - they must be active participants. The modules constantly pose questions to the student which test their understanding of the material being presented. Incorrect responses are adjudicated by the program and appropriate feedback is given to the student. Modules utilize multimedia to engage the user during the presentation of material and illustration of concepts and examples. Overuse of fancy graphics and multimedia "gimmicks" has been purposely avoided. "Cute" visual effects, such as happy faces (☺), are also rigorously avoided.
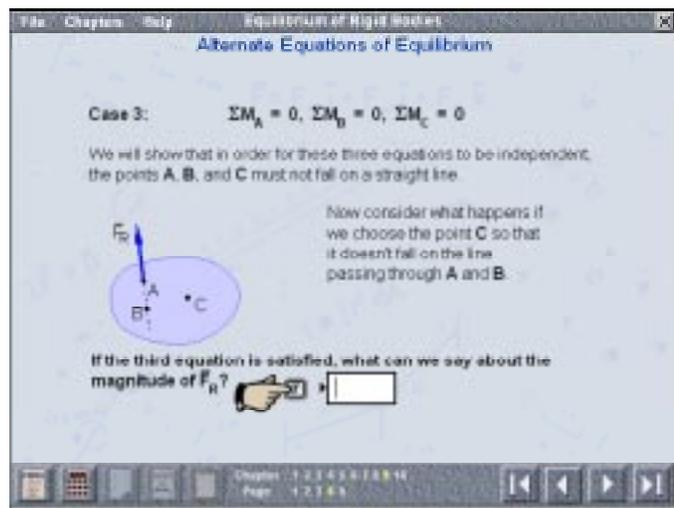
Figure 2 Example of a text interaction

Several different styles of interaction are used. These include simple interactions such as text response (see Figure 2), click responses (clicking on the correct answer from among several possible answers shown on the screen), and drag-and-drop responses (see Figure 3). The drag-and-drop responses are particularly effective in getting students to construct diagrams (such as free body diagrams) or to formulate equations. A wide variety of incorrect interaction responses are recognized and appropriate feedback can be given to the student about the error involved[2]. If the situation warrants, the student is directed to review the necessary parts of a lesson. Although many different responses to interactions can be judged, in the case of unanticipated responses, the student is advised to contact the instructor in person.
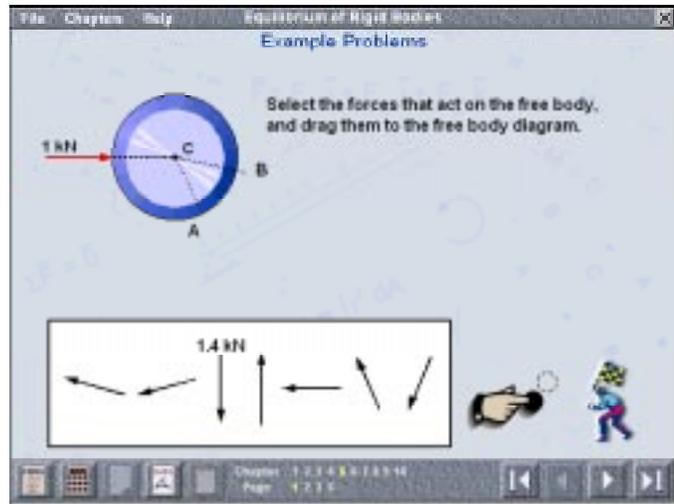
Figure 3 Example of a drag-and-drop interaction

Although not implemented in the current modules, in a networked setting it is possible to monitor and track student progress through the modules. Data (such as modules completed, sections within modules, fraction of incorrect responses, number of tries for each interaction, time spent in a module, and so on) can be collected and stored in secure files for each student. This would allow instructors to keep track of student progress through the course. However, since the modules are currently packaged for stand-alone (ie. at home) use, these bookkeeping capabilities are not yet implemented.

**Classroom Testing and Student Response**

The ENPH 131 modules were classroom tested during Spring Session (May - June, 1997) and made available as a supplemental resource in Fall and Winter Session (September, 1997 - April, 1998). The ENGG 130 (Statics) modules were used as a course supplement in September - December, 1997. At the time of this writing, only student survey results and comments for the ENPH 131 Spring Session course were available. In that course, the modules were used for primary delivery of about half the course material, with computer labs alternating with standard lectures. Evaluation consisted of an initial survey/questionnaire, a mid-course discussion group, a final survey/questionnaire, and a final discussion group that was taped and transcribed. The project principals were not present at any of these evaluation sessions. The major purpose of this formative evaluation was to identify operational bugs in the software and to assess the general student response.

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[2] Our record for anticipated feedback options is 256 separate feedback responses by the CBL module on a single drag-and-drop interaction.

Some interesting data arose from the questionnaires however two factors prohibit an exhaustive statistical examination of these survey results. First, the sample size was quite small (n = 25). Secondly, the class demographics were not typical of a regular class since most students who took the course had either experienced some academic difficulty (such as failing a prerequisite) or were repeating the course after failing. Nonetheless, as a measure of student attitudes and perceptions, some results obtained are worthy of note.

Students were generally satisfied with this mode of instruction (see Figure 4), although this overall impression declined from an initial survey (first day of classes) to the final survey (last class). This is not uncommon (termed the "halo" effect) with new technology, and is also due to many other factors (proximity to final exam?). Students generally appreciated the interactive style of the tutorials, especially the drag-and-drop interactions. Some students did not view the feedback as "valuable", although it was noted during observation in the computer lab that many students did not appear to spend a lot of time reading the feedback on incorrect responses. This was particularly noted during multiple choice interactions, where students would often just select (seemingly at random) from the list of options until the correct item was chosen, without bothering to read or think about the feedback offered on incorrect responses.
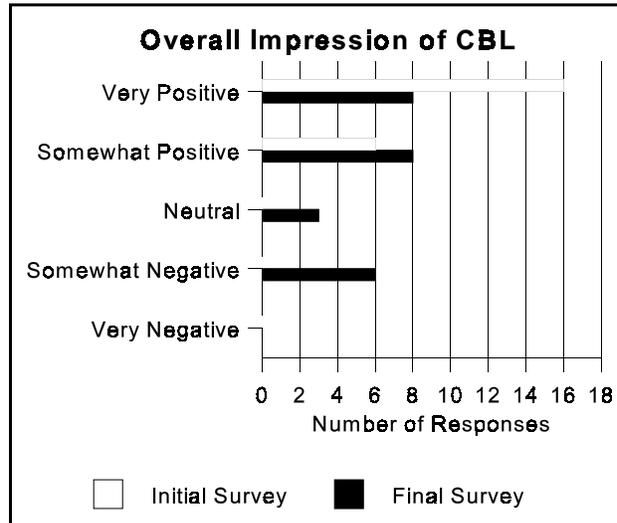
Figure 4 Survey question: "What is your general or overall impression of the CBL modules?
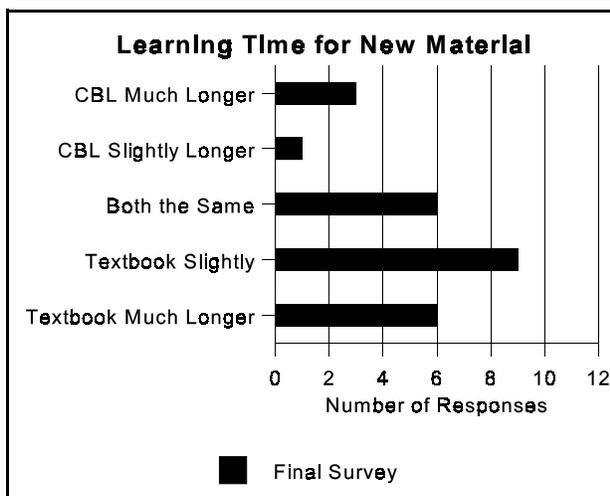
Figure 5 Survey question: "Which mode of delivery takes the longest to learn new material?" (CBL or textbook)
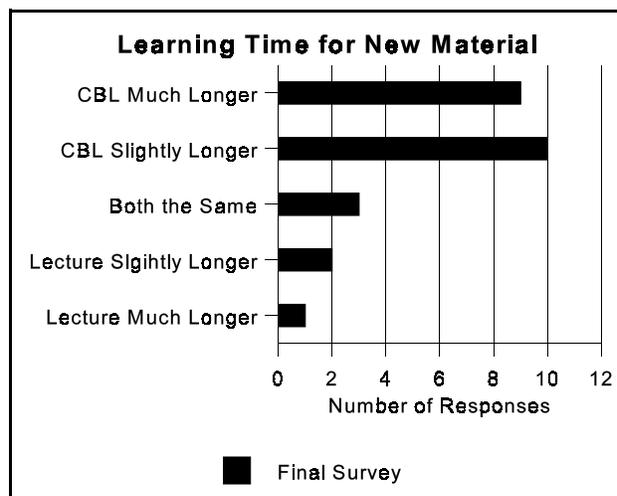
Figure 6 Survey question: "Which mode of delivery takes the longest to learn new material?" (CBL or lecture)

Figures 5 and 6 show that students generally ranked the CBL modules in between lectures and textbook studying in terms of the time required to learn new material. In the discussion groups, students indicated that they are more likely to view the modules as a computerized textbook than as a programmed lecture.

An interesting comment from several students indicated their preference to have a "sage on the stage" telling them what was important. Indeed, they felt this was their "right" since they had paid tuition for the course. Thus, they felt their fees were to provide them with an instruct*or* (who "gives good notes"), rather than instruct*ion*. This points to a deeper pedagogical consideration concerning the learning style preferences of the students, and may be related to the level of maturity of the students. It must be remembered that students entering a University program have experienced many years of teacher-led instruction. As such, students have an inertia associated with their learning styles as much as academe does with adopting new technology for course delivery[3]. It must be remembered that most students have arrived at the University by becoming proficient with the traditional system of instruction [4].

Most students viewed the modules as supplemental to the course, despite information to the contrary from the course instructor. Also, most students said they would be more inclined to use the software if course credit was assigned for each module completed. Several students had experienced this reward system previously.

Students generally viewed the courseware as a vehicle for review and exploring additional examples, rather than for primary delivery (see Figure 7). Other issues raised by the students were related to accessibility to computers, uncertainty about when to take notes, and various aspects of the program design[4].
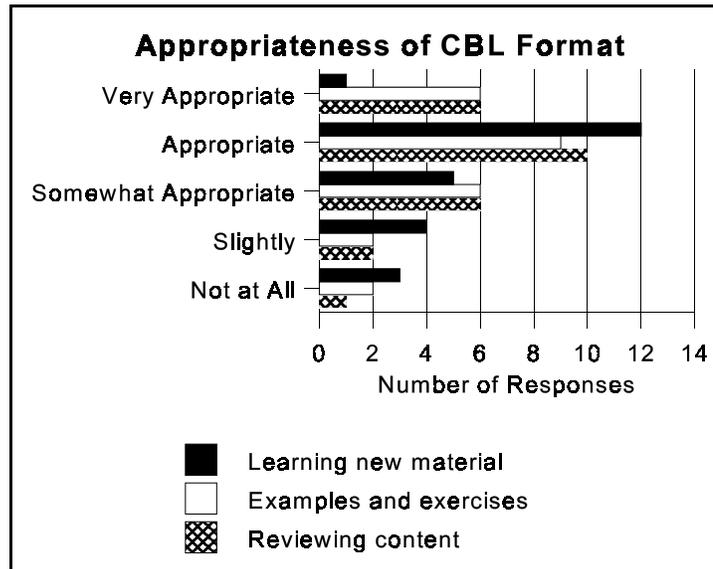

Figure 7 Survey question: "In general, how appropriate did you find the computer format in [the three indicated areas]?"

Although it is not possible to draw very strong conclusions about the efficacy of the modules, it was noted that the Spring Session class obtained a better overall class average than any similar class for the past several years. In addition, the instructor felt "more relaxed" once the pressure for planning and preparing daily lectures was somewhat reduced.

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[3] The "they" in the title of this paper refers as much to academe as it does to students!

[4] One student indicated that the feedback was uniformly "too cheerful" - he just wanted to be told when he was wrong, without a lot of extra hints or support.

Conclusion

Educators need to provide alternative strategies and options for learning. Initial success with these modules has encouraged us to continue with their development, and to more fully integrate them into the curriculum. The serious problems of accessibility to computers will be alleviated in the near future by plans for mandatory computer purchase by all incoming students[5]. Changes to the modules will allow instructors to track student use and performance.

In order to be successful with this mode of delivery, it is necessary to undertake some very careful promotion with the students. They must "buy in" in order that their initial enthusiasm can be maintained. It is necessary to explicitly point out reasons and advantages (and disadvantages, for that matter) for using new technology as a learning tool. Furthermore, it must be impressed upon students that learning is an activity for which they must take primary responsibility, thus shifting the attention (from the faculty perspective) from *teaching* to *learning*. This is not only to make them more effective learners (in identifying their preferred mode of learning, for example) but also to prepare them for life after graduation. Students must be prepared (and encouraged) to experiment with different learning styles and resources. In preparing students for a world of life-long learning, this may be the most important thing "learned" at the University.

Future plans for the existing modules include the addition of more example problems for the students to solve, and additional multimedia elements such as video. It is also planned to develop more quizzes, on-line assessment modules (student performance tracking), additional delivery mechanisms (CD-ROM), and, finally, to investigate methods for wider dissemination of this work..

Acknowledgement

References

[1]   Murray, M.H., "Better Learning through Curricular Design at Reduced Cost", J. of Engineering Education, November, 1997, pp. 309 - 314.

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[5] Current Faculty requirements are only that each student should shall have "assured access" to a "personal, portable, computing device."

[2]   *Authorware Professional*, Macromedia, Inc., San Francisco, http://www.macromedia.com/software/authorware.

[3]   *InstallShield* and *InstallFromTheWeb*, InstallShield Software Corporation, Schaumburg, Illinois, http://www.installshield.com.

[4]   *Implementing Instructional Technology*, Stanley Varnhagen, ATL, University of Alberta, http://www.atl.ualberta.ca/demos/idesign/focus.htm

Biographical Information

ROGER TOOGOOD
Dr. Toogood joined the Department of Mechanical Engineering in 1983. He has taught and developed software-based learning tools for a number of courses (fluid mechanics, robotics, dynamics, engineering graphics and design, computer analysis of mechanisms). His research interests are in areas of instructional technology, robotics, genetic algorithms for design optimization, and applications of artificial intelligence to conceptual mechanical design.

BILL LIPSETT
Bill Lipsett obtained his Ph.D. from the University of British Columbia in 1985 where he conducted research on the dynamics of offshore structures. After joining the Mechanical Engineering department, he has maintained his interest in nonlinear dynamics and biomechanics. Bill has taught undergraduate and graduate courses in engineering mechanics, design, dynamics of structures, and numerical methods.

SHELLEY LORIMER
After receiving her Ph.D. Dr. Lorimer worked for five years doing reservoir modelling at the Alberta Research Council before returning to teaching. She has taught undergraduate courses in engineering, mathematics, physics and computing science at the University of Alberta, Concordia University College, and Grant MacEwan Community College, where she is currently teaching in the Engineering Transfer Program.

TERRY HRUDEY
T.M. Hrudey has been a faculty member at the University of Alberta since 1976. He is currently Professor and Chair of the Department of Civil and Environmental Engineering. He has taught undergraduate and graduate courses in mechanics, numerical methods, and the finite element method. His research interests are in the areas of constitutive modelling, ice mechanics, and finite element methods.

ART PETERSON
Art Peterson has a number of years of government and private sector surveying and mapping experience prior to joining the University of Alberta in 1983. His research activities include Doppler and inertial surveying, hydrographic surveying, photogrammetric applications programming, and consulting in CAD/CAM applications. Prof. Peterson has taught a number of undergraduate courses, including the first year statics course.

STANLEY VARNHAGEN
Stanley Varnhagen has a Ph.D. in Educational Psychology from the University of California, Santa Barbara. His speciality is in program evaluation and research, in the area of educational technology. His major responsibility at the University of Alberta is in assisting and training faculty to evaluate their instructional technology projects.