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Students Consolidate Learning by Designing Course Modules*

G. W. BRODLAND†
Department of Civil Engineering, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1
G. WELSTEAD‡
Engineering Education Research Centre, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1

This article describes a novel approach to help students consolidate the knowledge they have acquired during an engineering course. Students construct a 'conceptual map' illustrating the relationships between basic concepts from one part of the course with which they had difficulty. Using this as a framework, they then design a Computer Aided Instruction (CAI) module that would help other students learn at least one of these basic concepts. Students are guided through this process using a series of assignment format questions. A variety of preferred learning styles is accommodated, and courseware is produced for future classes.

INTRODUCTION

THE INCREASING breadth and depth of engineering knowledge and the resulting pressure to cover more material in less time has meant that, in a typical semester, students have little time to consolidate what they have learned, much less to see their courses in perspective. A first Mechanics of Solids course, where students encounter numerous new concepts which are vital to their understanding of subsequent courses, is a prime example of a course vulnerable to this problem. The fact that many students are intimidated by the associated mathematics further aggravates the situation.

For this project, we set out with two complementary objectives in mind. Our principal objective was to provide current students with an opportunity to consolidate their knowledge; i.e. to understand the course material well enough to see the relationships between the various concepts in the course on a broad scale. As Hayes [1] so clearly argues, recognizing the relationships between ideas is vital to the learning process. During the course of the project we came to learn how badly students need this opportunity.

According to Whitehead [2], the learning process includes three stages: romance, precision, and generalization. Most engineering courses concentrate on the precision aspect, to the detriment of the equally important first and third stages of this learning cycle. In this project, we encourage students to design 'conceptual maps' showing the relationships between parts of the course. We hoped that by having them do this, consolidation of the course material would occur, and that a foundation for some degree of generalization would be laid.

Our secondary objective was to have students design instructional modules (such as computer tutorials or laboratory experiments). This required the students to consider, in detail, the relationships between the concepts relevant to some small part of the course. It also required them to take a different mindset—that of instructor or tutor. Since students are often keenly aware of which concepts in a course are the most difficult to grasp and how it was that they finally came to understand a certain concept, it makes sense to involve them this way in courseware development. In addition, this approach provided instructional modules which could be used in future classes.

PROJECT DESIGN

Students clearly need some guidance in this process. We decided to provide this guidance through a series of assignment format questions which could be appended to the typical weekly problem set. This approach provided step by step direction and included discrete deadlines which could be spread over a period of several weeks if desired.

The questions were designed to meet the following criteria:

1. Questions would require students to understand, define, and organize the course material for themselves.
2. They would lead a student, through a sequence of manageable steps, to a point where he or she could write useable instructional modules.

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† G. W. Brodland is Assistant Professor.
‡ G. Welstead is graduate student.

3. Most questions should take no longer than approximately thirty minutes to complete. (This was the average time required for other questions in a typical assignment.)

Our intent was to integrate the special questions (the 'X-Problems', as we called them) into the regular course assignments as smoothly as possible. We felt it was important that the exercise not be perceived by the students as creating a significant amount of additional work. An abridged version of the X-Problems is shown in Fig. 1.

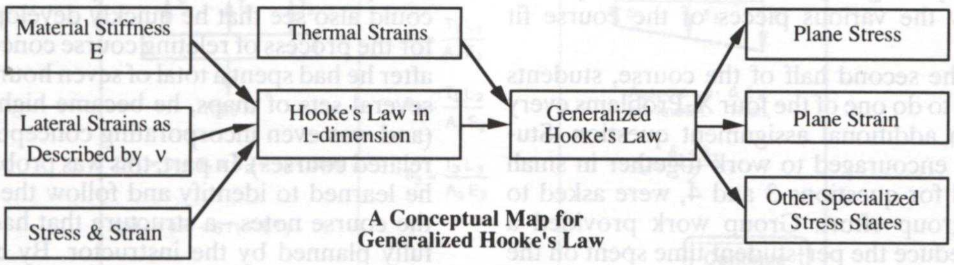
Our X-Problems (especially question 4) were oriented towards the generation of useable storyboards (computer screen layouts) for future programming. The idea could be expanded to include student development of a limited-domain expert system module, or something as different in structure as a laboratory format learning module. Indeed, having gone through this exercise, we are inclined, in future, to allow students to choose the format of the module they design.

CIV E 204 - Mechanics of Solids I
X-Problems

1. What do *you* see as being the role of the following components of this course?

a. Lectures, b. Tutorials, c. Assignments, d. This Exercise, e. Final Exam.

2. Choose a small section of the course, such as "Statically Indeterminate Problems" or "Generalized Hooke's Law", and list what you believe to be the key ideas in that section. (You'll benefit most if you pick one with which you had some degree of difficulty). Then, use a diagram to show how those ideas relate to each other and how they build on previous concepts in the course.



A Conceptual Map for Generalized Hooke's Law

3. If *you* were to teach the part of this course related to your chosen topic next term, in what order would you teach the concepts and by what means (e.g., lecture, demonstration, experiment or computer aided instruction). At what stages would you provide the student with a chance to respond by doing problems, a computer tutorial, etc.? It is fine if you feel the computer is not an appropriate tool to teach or review any part of your chosen topic.

4. Describe a possible computer tutorial related to part of this course (it need not be the area you covered in questions 1 - 3). Clearly state the objective(s) of that tutorial. Then, based on the sample handout and the demonstration you saw of "Course of Action", write approximately 12 "storyboards" to cover at least a part of that tutorial. Alternatively, you may, in consultation with your instructor, develop an entirely different type of instructional module, such as a laboratory experiment.

You may want to include some or all of the following in your set of storyboards:

a. Title and introduction
b. A brief reminder to the student of the key concepts in the section
c. Sample worked problems
d. Assignment-type problems for the student to do
(*any problems given here must be of your own design*)
e. The opportunity to do more sample problems

Assume that the following are continuously available through "pull down" menus:

a. Tables of material properties
b. Tables of properties for common structural sections

Fig. 1 Abridged version of the 'X-Problems'

IMPLEMENTATION

Poisson's Ratio is one of the fundamental concepts of solid mechanics which is covered early in the course. To introduce students to the potential of Computer Aided Instruction (CAI) software, an interactive tutorial on Poisson's Ratio was written on a *Macintosh*™ computer using an authoring system called *Course of Action*©. Our discovery of Course of Action made us realize that powerful courseware authoring tools are now available, and, in part, prompted this project. The computer demonstration consisted of simple animations (exaggerated deformation of a prismatic member under axial load), worked examples, and typical assignment questions. In addition, there were conceptual problems designed to challenge students and encourage generalization of the material.

A computer projection system was used to provide an in-class demonstration of the tutorial program. During the demonstration, we attempted to describe to the students some of the potential advantages of CAI courseware. We pointed out that their participation in the project could help them to understand the course mateial as they endeavored to teach it to someone else via the modules they designed, and that it would help them to see how the various pieces of the course fit together.

During the second half of the course, students were asked to do one of the four X-Problems every week as an additional assignment question. Students were encouraged to work together in small groups and for questions 3 and 4, were asked to submit a group effort. Group work provided a means to reduce the per-student time spent on the exercise. It was also felt that the quality of the finished product would be higher if students, as the ultimate users of the materials, could collaborate on the module design and test their ideas on one another.

The timing of the project over the second half of the course was optimal in that students had covered enough material to be able to identify areas with which they were having difficulty. At the same time, they were not overwhelmed with a large project at the end of the term.

STUDENT SUBMISSIONS

In one class of ninety students, most participated in one of the twenty-five groups that handed in sets of storyboards. More than a third of these sets seemed worthy of future integration into actual instructional modules. With student consent, these were photocopied and retained for future implementation. One group chose to exercise the option provided in Question 4, and designed a laboratory experiment.

Re-drawn excerpts from two sets of student-submitted storyboards are illustrated in Figs 2 and 3. The first of these shows the statement of a statically indeterminate problem, and a clear exposition of the first steps in its solution. It was the students' idea to place the three types of simultaneous governing equations used to solve the problem in adjacent columns. The two students who prepared the second set of storyboards (Fig. 3) obviously enjoyed the task, and felt it was appropriate to include a vote of confidence for their teaching assistant, Allan.

Although the storyboards and lab experiment submitted were done quite well, the conceptual maps, for the most part, were not. In order to understand this, and to gain insight into the process by which students developed their answers to this key part of the exercise, a student was asked to develop several additional conceptual maps. Figure 4 shows one of the results of this individual's efforts.

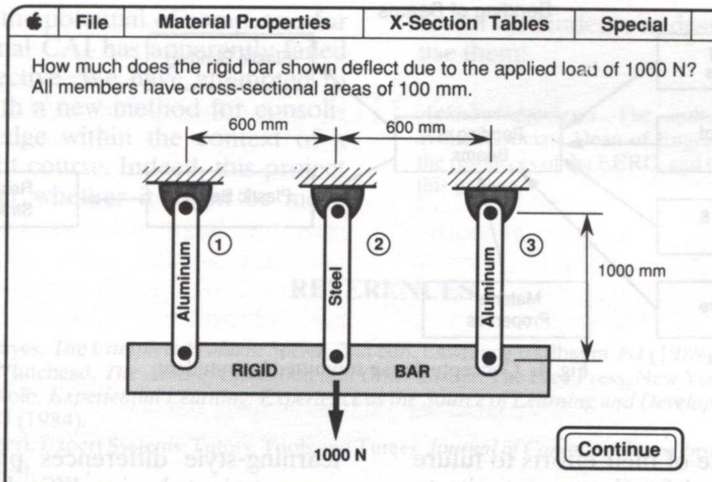
Since the students also submitted the rough drafts of his maps, we were able to trace the substantial development of his understanding of how particular course concepts were related. We could also see that he quickly developed a facility for the process of relating course concepts. Indeed, after he had spent a total of seven hours developing several sets of maps, he became highly proficient (and was even incorporating concepts from other related courses). In part, this was probably because he learned to identify and follow the structure of the course notes—a structure that had been carefully planned by the instructor. By completing a similar exercise ourselves, we were reminded that even instructors of the material require several iterations to develop effective conceptual maps.

STUDENT REACTION

In order to obtain a quantitative measure of student reaction to the project, a questionnaire was prepared and administered at the end of the term. A five-point rating scale was used. Sixty-three of the students responded.

When asked whether the benefit they derived from doing each of the X-Problems was worth the thirty minutes (average) per question they each spent doing them, the most positive overall response was to the conceptual map question—the one we felt was answered most poorly! On the other hand, students felt that the hour and a half on average they spent doing question 4 (storyboard development) did not provide good value. None the less, more than one third of the class felt that collectively, the X-Problems did provide them with good value for time spent.

Written and verbal comments indicated that many students gained insight into the course material as a result of the project. Some students



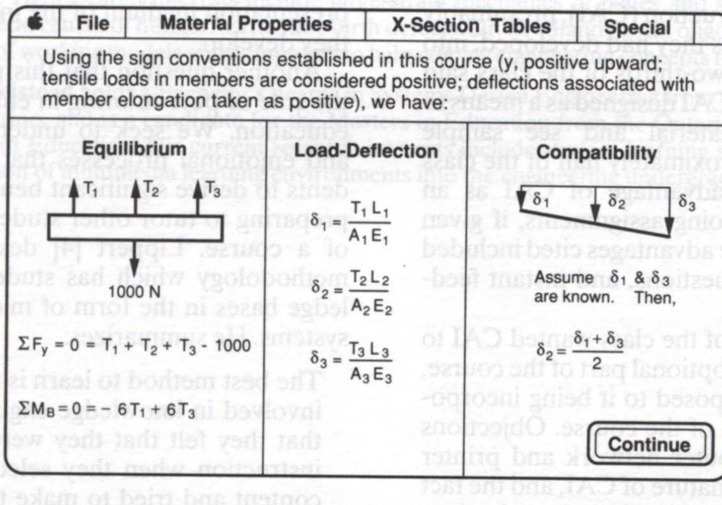


Fig. 2. Excerpt from a student storyboard submission—statically indeterminate problem

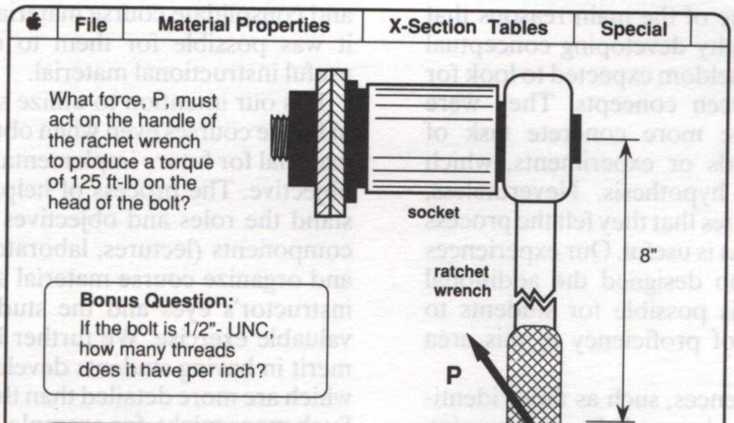


Fig. 3. Student Storyboard Submission—Torque Problem

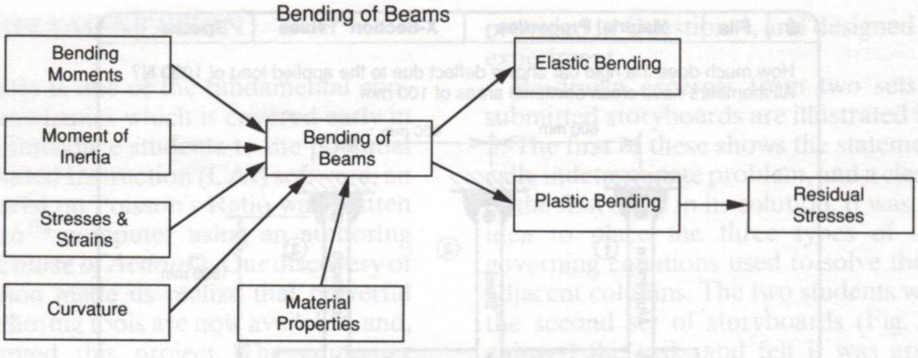


Fig. 4. Conceptual map submitted by a student

also recognized the value of their efforts to future classes. A few even asked for the opportunity to participate in future courseware development, especially computer based tutorials.

The second part of the questionnaire measured student response to possible future incorporation of Computer Aided Instruction (CAI), presumably based on the storyboards they had developed, into the course. More than two-thirds of the class said they would make use of CAI designed as a means to review the lecture material and see sample problems worked. Approximately half of the class said they would take advantage of CAI as an alternative means for doing assignments, if given the opportunity. Specific advantages cited included a 'limitless' supply of questions, and instant feedback.

Although two-thirds of the class wanted CAI to be made available as an optional part of the course, more than half were opposed to it being incorporated as a required part of the course. Objections included possible computer network and printer failures, the impersonal nature of CAI, and the fact that they already spend too much time staring into computer screens.

DISCUSSION

We postulate that one of the main reasons that the students had difficulty developing conceptual maps was that they are seldom expected to look for the relationships between concepts. They were fairly successful in the more concrete task of constructing storyboards or experiments, which further supports this hypothesis. Nevertheless, student feedback indicates that they felt the process of formally relating ideas is useful. Our experiences with the individual who designed the additional maps suggests that it is possible for students to develop some degree of proficiency in this area fairly quickly.

Learning-style differences, such as those identified by Kolb [3] may shed some light on this point: while a conceptual map may be an appropriate representation for an abstract, spatial learner, a linear thinker may prefer a detailed course outline approach for organizing the subject matter. Thus, learning-style differences probably account for some students having difficulty producing conceptual maps, which are more free-form. As a result, we will, in future, allow students to choose the medium they use to organize course concepts (e.g., conceptual maps or detailed outlines), as well as the presentation medium of the instructional modules they develop.

Another question that this project has raised is the role of peer tutoring in enhancing engineering education. We seek to understand the cognitive and emotional processes that enable certain students to derive significant benefits from the act of preparing to tutor other students in specific areas of a course. Lippert [4] describes a promising methodology which has students develop knowledge bases in the form of microcomputer expert systems. He summarizes:

> The best method to learn is to teach . . . students involved in knowledge engineering commented that they felt that they were in effect planning instruction when they selected and sequenced content and tried to make the various relationships within the content explicit.

We are satisfied that it was possible, with minimal time expenditure from both instructor and students, to use an appropriately designed assignment problem format to help students to organize and consolidate course material. At the same time, it was possible for them to develop potentially useful instructional material.

It is our intention to utilize similar problem sets in future courses even when obtaining instructional material for future implementation is not a specific objective. The process of helping students understand the roles and objectives of different course components (lectures, laboratories, tutorials, etc.) and organize course material appears, in both the instructor's eyes and the students' eyes, to be a valuable exercise. We further believe that there is merit in having students develop conceptual maps which are more detailed than those illustrated here. Such maps might, for example, trace the individual steps of an important derivation.

Learning how to organize information and concepts may be one of the most important objectives of an engineering education. While proponents have extolled the potential of computers for teaching, conventional CAI has apparently failed to address this objective. We have attempted to provide students with a new method for consolidating their knowledge within the context of a conventionally taught course. Indeed, this project has made us wonder whether it might be more useful for students to design CAI modules than to use them!

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G. Wayne Brodland, Ph.D., P.Eng., is an Assistant Professor in the Department of Civil Engineering at the University of Waterloo. He holds a cross appointment to the Department of Biology. His research interests include large-strain mechanics of plates and shells, and the mechanical causes of human neural tube birth defects. Dr. Brodland has an ongoing interest in the use of working models and computers to help convey engineering concepts to his students.

Greg Welstead holds a Bachelor's degree in Systems Design Engineering from the University of Waterloo, and is a candidate for the Masters in Education from the Ontario Institute for Studies in Education. His current research interests include student learning styles, and the integration of multimedia learning environments into the engineering undergraduate system.