

## Technology-based Innovative Teaching Methods

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### **Abstract**

Innovative ideas on efficient teaching has been developed and tested in class as a result of more than 15 years of experimentation with courseware development and implementation using a variety of hardware, software, application programs and methods of delivery, including Web-based teaching and testing. The best learning results were observed when students had to solve program-generated realistic problems right after the lecture using step-by-step method. The program provided judgment, feedback and help after each step. Correct answer was given after three wrong ones allowing students to proceed with the problem. Students were allowed to repeat the work because the program generated a new problem each time. The final solution was always correct but the score was reduced at each step by the points lost at each wrong answer. The paper describes how these ideas can be implemented using a variety of available authoring software. Student evaluation of these methods of teaching will be presented.

### **I. Introduction**

The author started developing courseware in Statics and Mechanics of Materials in 1982. At that time she was working at Computer-Education Research Laboratory (CERL) at the University of Illinois at Urbana-Champaign (UIUC) and teaching in the School of Architecture at UIUC. The first mainframe based computer education system PLATO was developed at CERL. The system underwent many transformations as the communication technology was improving and it exists now as a private enterprise named "NovaNET". The NovaNET programs are available and were used in author's classes whenever UIUC agreed to pay for NovaNET services.

All the features of NovaNET and more were incorporated in cT authoring environment developed at Carnegie-Mellon University. The author developed a package of 10 Statics lessons using cT 3.0. This development was partially sponsored by a grant from NSF<sup>1,2,3</sup>. All Statics lessons are continuously used in teaching Statics in the School of Architecture at UIUC. Upon evaluation of the lessons' effectiveness they were significantly improved. The package is available on a Zip disk or CD from CompuCollege (helenk@uiuc.edu).

The Web-based interactive homework assignments and quizzes were developed using Mallard <http://www.ews.uiuc.edu/Mallard/>. As of today there are 17 Mallard lessons in Statics and 14 lessons in Mechanics of Materials. The author and other instructors teaching these subjects in the School of Architecture use all the Mallard lessons.

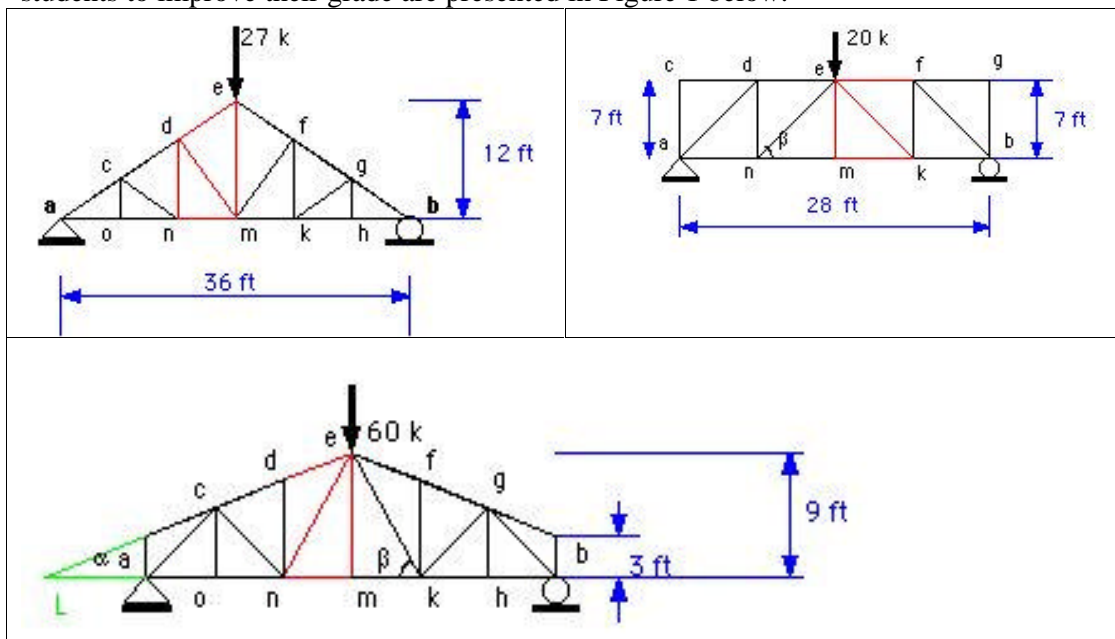
### **II. Innovative Features of Teaching and Testing Courseware**

The cT lessons can incorporate the best teaching features described in the abstract. These lessons are used as homework assignments. Necessity to solve problems stimulates students' questions related to the subject matter. The Help sequences and Feedback remarks at the wrong answers provide an easy access to the ways to find the correct answers by learning the appropriate theory and by following certain procedures. This approach is opposite to what is usually done by lecturing when we answer questions generated in the process of the lecture. These are not students' questions and they are not interested in our answers to the degree necessary for the effort to understand the answers.

Students can learn from their mistakes only when they are exposed to a new problem similar to the previous one but at the same time different enough to require some new thinking on the students' behalf. The stimulus is to improve their grade for the homework. This idea works the best when students do their homework assignments of problem solving in computer labs using our programs which generate (not choose from a list) a new problem at each execution time. Each time a sophisticated topic-specific algorithm is used for problem generation.

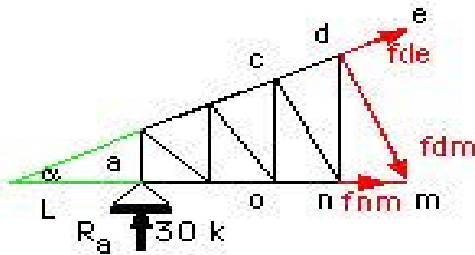
Students have a question-specific feedback each time their response is wrong. Process of learning through experience is achieved by allowing students to solve a renewed set of problems of the same type. This approach is possible only for computer-graded problems considering usual large student per faculty ratio.

To be really educational the problems have to present an appropriate challenge. Examples of programs generating a variety of new challenging problems in a sequence of attempts by students to improve their grade are presented in Figure 1 below.



**Figure 1.** A variety of problems presented in the same lesson in a sequence of execution times. The students are asked to determine forces in the members of the truss shown in red using method of sections.

Lesson "Trusses, Method of Sections" is a cT lesson and it required a rather sophisticated programming. The program generates numerical data for the following parameters of the truss: the length of the truss, horizontal distance between the joints, number of joints in the horizontal bottom cord, height in the middle of the truss, and the height of the truss at the support. Three types of the orientation of diagonal members are shown in the three examples in Figure 1. The computer starts drawing from the middle of the truss. The same letters always mark the six middle members of the truss because these members may be the objects of problem questions. This approach allows generating a numerous variety of trusses while using relatively small number of parameters. The step-by step questions are the same no matter how different are the trusses (Figures 2 and 3) while the answers to the questions are of cause depend on the numerical data for the truss parameters.



**Figure 2.**  
**FBD of a selected truss portion.**

The Free Body Diagram (FBD in Figure 2) appears on the screen after student's choice of members to be cut and the truss portion to be considered. After the student evaluates angle  $\alpha$ ? equilibrium equations containing only one of the forces in question have to be written on the screen. The program judges the equations written by students on the screen. An example of questions is shown in Figure 3.

Considering the Free Body Diagram of the truss portion shown in the sketch, you can write three equilibrium equations and solve them for the three unknown forces.

It is convenient to choose the equilibrium equations so as to have only one unknown in each.

Make your first choice of the equation to solve for the force in the **upper chord**:

>

1)  $\Sigma F_y = 0$ ;    2)  $\Sigma F_x = 0$ ;    3)  $\Sigma M_a = 0$ ;  
 4)  $\Sigma M_b = 0$ ;    5)  $\Sigma M_d = 0$ ;    6)  $\Sigma M_e = 0$ ;  
 7)  $\Sigma M_f = 0$ ;    8)  $\Sigma M_k = 0$ ;    9)  $\Sigma M_m = 0$ ;  
 10)  $\Sigma M_n = 0$ ;    11)  $\Sigma M_L = 0$ ;    12)  $\Sigma M_R = 0$

At the arrow type the number of the equation you have chosen.

Notations L and R identify points of intersection of the upper and the lower chords when the points lie outside of the truss body.

**Figure 3.** Screen display providing students a list of equilibrium equations to choose from. The list contains right choices for any possible situation. The unknown should be either a force in the upper chord, or the one in the lower chord, or the one in the diagonal member.

$\Sigma M_m = > \cdot -30*16 - fde*\cos(\alpha)*12 \quad \text{ok}$

At the arrow write the expression for the moment about point m of all the forces acting on the truss portion exposed in the Free Body Diagram.

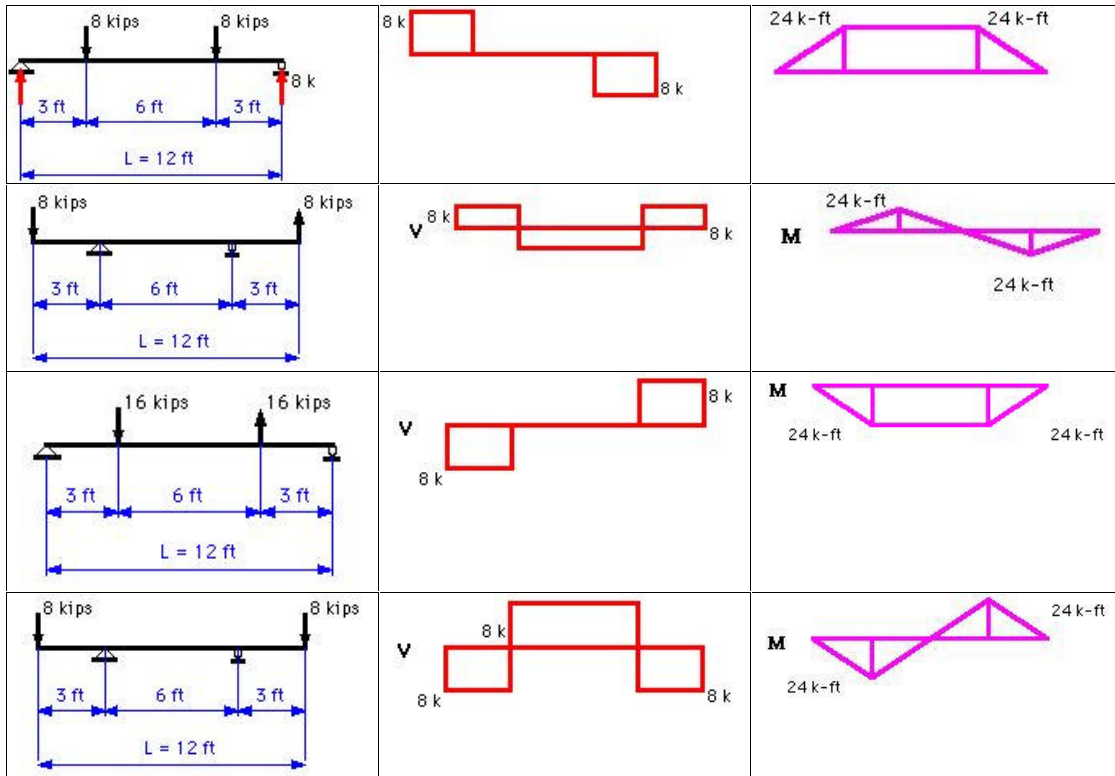
Use notation alpha instead of the angle value. Example:  $\cos(\alpha)$  instead of  $\cos(18\text{DEG})$ .

**Figure 4.** Screen display with judgement of the answer typed in by the student. The alphanumeric expressions in student answers are judged numerically. The expression is saved and then calculated for the actual value of data variables and three reasonable values of the variable to be found (not the actual one for equilibrium equations to avoid zero result). The ok judgement means that all three results are the same as they are expected to be.

Similar approach is used in all cT lessons. Through many years of usage of my cT lessons students always considered them very helpful for learning the subject.

The latest development in our experimentation with technology is using Mallard authoring web-based software for developing and implementing Web-based homework, quizzes and tests. Different ways of providing variety and continuity were developed for teaching in homework assignments versus testing in quizzes.

The judgment sophistication available in the Mallard is not the same as in the cT 3.0 where we could write a program for judging correctness of alphanumeric expressions. However, we found interesting opportunities for avoiding just multiple choice questions where wrong answers have to be considered by students. We used a matching type of questions and presented no wrong answers. This turned out to be a very good learning experience as the typical misunderstandings by students of the rules to calculate bending moments in a beam using the shear force diagram were exploited.

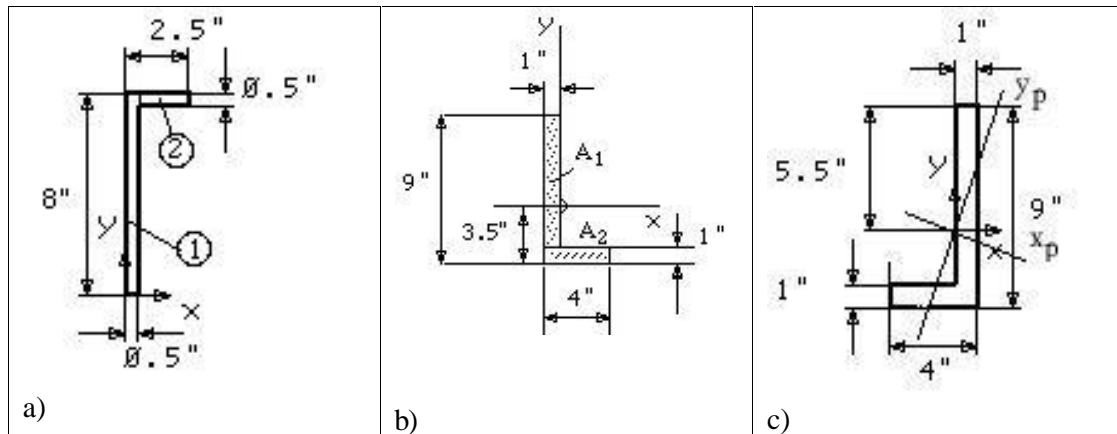


**Figure 5.** Examples of contents for matching questions where four beams of the same length with different locations of supports and the load have to be match with the appropriate shear force and bending moment diagrams.

The set up of Mallard quizzes is intended for testing. Each quiz can incorporate several questions. However the questions cannot be judged in a sequence. The entire quiz has to be submitted for judging. This prevents possibility of using step-by-step judging approach that works very well for teaching. It was observed that students learn better when they are exposed to correct solution at each step right after making their mistakes. They learn from their experience, and having the second chance of solving a similar problem can improve their grade. To provide students with a learning experience of this type we used the flexibility of setting up our own grading policy in Mallard by allowing students to retake the quiz. Each question in Mallard may have many versions and the student always sees a new version at each repetition unless there is not enough versions available.

Here is the problem set up that was used for a homework assignment on Mallard. A long problem was divided in several reasonable parts and each part was formulated as a separate

question. Similar problems were developed for a variety of question versions. However the problems were significantly different to present a new challenge to students. The sequence of questions in one quiz never had the same problem covered in the questions displayed at the same time. An example of such an approach is shown in Figure 6.



**Figure 6.** A problem of finding principal axes and the principal moments of inertia of an area is divided into three problems. First - it is a) finding a centroid of an area. Second - it is b) calculating the moments of inertia of a similar but different area about its centroidal horizontal and vertical axes shown in the sketch. The last is c) answering the main question and identifying in the sketch the direction of buckling for a column with this cross-section and the principal axis about which the moment of inertia is minimal.

The Mallard lessons are easier to develop than cT lessons. The review of Mallard lessons being used in teaching architecture courses in Statics ARCH 251 can be done at the following URL: <https://www-s.etb.uiuc.edu/ARCH251/> The URL for Mechanics of Materials course ARCH 252 is: <https://www-s.etb.uiuc.edu/ARCH252/> The NetID to be used is archguest/mallard, the password is helenk.

All cT lessons generate a score that is stored in file "statics.dat" in the same folder where all the cT programs are located. Recently it became possible to have the entire package on a zip disk so that the grade with the student's name and the lesson name can be stored on the same zip disk and then submitted to the instructor for the record. Mallard has a sophisticated grading system that can include a custom designed variety.

Students' evaluations of computer-based homework assignments were recorded in our annual questionnaires for many years. More than 90% of students usually find the lessons very valuable for understanding the subject and learning how to apply theory to problem solving.

### Bibliographic Information

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#### Biographical Information

Helen Kuznetsov is a Research Associate Professor at the School of Architecture, University of Illinois at Urbana-Champaign. Previously she was an Assistant Professor at Engineering Mechanics Department at the Ohio State University, Columbus, Ohio. She continuously authored a variety of computer -based courseware since 1982.