Learning about Trusses with Multimedia

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Abstract - *We are developing a learning environment in the subject area of statics that includes physical models, interactive multimedia, traditional pencil-and-paper activities, and cooperative learning in the framework of experiential learning (Kolb, 1984). We are using Authorware Professional to construct the multimedia program. We taught a section of statics in this format, which now includes topics from mechanics of materials, for the third time in the fall of 97 to students in architecture. In this paper we describe briefly the learning environment (Holzer and Andruet, 1998) and illustrate how students are guided to learn about trusses.*

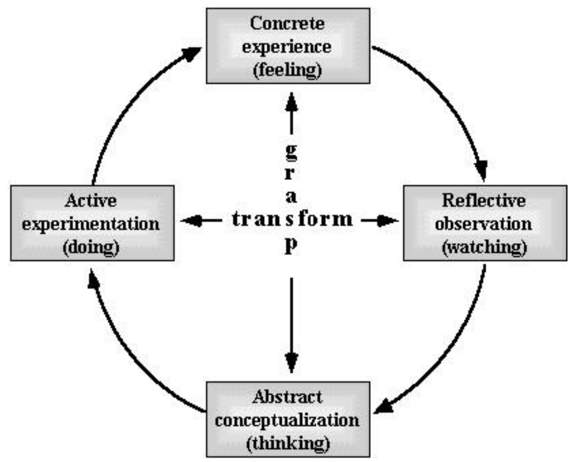

Figure 1. Experiential Learning Model (Kolb, 1984, p. 42)

Learning Environment

> *Learning is the process whereby knowledge is created through the transformation of experience.*
> **David Kolb** (1984)

Experiential learning focuses on the two fundamental activities of learning: grasping and transforming experience (Fig. 1). Each activity involves two opposite but complementary modes of learning. One can grasp an experience directly through the senses (sensory, inductive mode) or indirectly in symbolic form (conceptual, deductive mode). Similarly, there are two distinct ways to transform experience, by reflection or action. At any moment in the learning process, one or a combination of the four fundamental learning modes may be involved. It is significant that their synthesis leads to higher levels of learning (Kolb, 1984). This is confirmed in a study by Stice (1987), which shows that the students' retention of knowledge increases from 20% when only abstract conceptualization is involved to 90% when students are engaged in all four stages of learning.

Our class meets in a computer lab where two students share one computer. This facilitates cooperative learning where the pair is the basic unit.

Examples of cooperative learning structures for pairs include think-pair-share (**TPS**) (Lyman, 1987) and think-aloud-pair-problem-solving (**TAPPS**) (Lochhead, 1987). We found that in the classroom environment, teams of two students are more effective than teams of three or more students because the one-on-one interaction of a pair can accommodate students with diverse characteristics. In groups of three or more students, one student is frequently left out. For example in **TAPPS,** where one student is the problem solver and the other the listener, the roles of the members are so well defined that cooperation is necessary. Once students have become experienced with **TAPPS,** they may prefer a more flexible version that permits collaboration during the solution process. This was recommended by students experienced in **TPS**; now we use a modified version which we call **MTAPPS.**

Learning about Trusses

We learn about trusses by identifying their characteristics, constructing mathematical models, and analyzing models of trusses (Fig. 2). The analysis of trusses (Fig. 3) is divided into **member forces**, to develop concepts of two- and three-force members (Holzer and Andruet, 1998); **methods of analysis**, which includes their development (inductive) and summary (deductive); and the solution of **problems.**

Method of Sections

Here we illustrate the development of the method of sections and its application in the solution of two truss problems.

Development

The objective is to learn how we can use sections of trusses to compute member forces. A section is an isolated part of a truss containing two or more joints. The development of the method of sections involves the first three stages of experiental learning (Fig. 1). Effective activities for the first stage are hands-on laboratory experiments that engage students directly through concrete experiences. Specifically, students may be asked to guess whether a member is in tension or compression and to measure member forces. It is simple to measure tensile forces with spring scales (Fig. 4), but it is not obvious how to measure compressive forces. This provides the opportunity for posing a puzzler, a very effective way to stimulate interest and involvement: how can we measure a compressive member force with a spring scale that records tension? Students are asked to work cooperatively in pairs to answer the question. The benefit of such experiences is the active involvement in learning and the process of discovering new concepts. The answer to the question is illustrated in Fig. 5. We use such experiments in a hands-on-statics laboratory, a pilot course supported by SUCCEED. Our goal is to promote the integration of elements from this pilot course in the standard engineering statics course.

Figures 4, 6, and 7 are concerned with the **analysis** (reflective observation) of the experiment and the formulation of an analysis **procedure** (abstract conceptualization) based on truss sections. We found that traditional pencil-and-paper activities (Manual in Fig. 4) facilitate learning with multi-media tools. Analysis results are displayed in Fig. 6. It is difficult for some students to realize that the member forces acting on one section represent the effect of the other section, the portion of the truss removed, and that free-body-diagrams are virtual concepts. The product of this development, the method of sections, is summarized and illustrated in Fig. 7.

Analysis of a simple truss

Figures 8-16 illustrate activities in the analysis of a simple truss that are inquiry-based to promote cooperative learning. The objective is to compute each member force directly from a single condition of equilibrium (Fig. 8.). The analysis process includes choices and questions. For example, one can select the member force (Fig. 9), the method of analysis (Fig. 10), and the condition of equilibrium (Fig. 14). Questions concern the choice of a section (Fig. 12), the assumed sense of a force (Fig. 13), and the equilibrium of the final FBDs of the sections (Fig. 16), which are constructed by the students. Figure 11 shows the integration of pencil-and-paper with multimedia activities. Figures 14 and 15 illustrate constructive feedback: generally, the program provides a clue in response to the first error in a small task and the solution after the second error.

Analysis of a complex truss

One objective of the problem in Fig. 17 is to compute the force in member 4 with the fewest conditions of equilibrium. The solution procedure is first discussed by students in teams (**TPS**). This is followed by a class discussion based on the solution in Figs. 18 and 19. The FBD for the computation of F_1 and feedback to the second error are displayed in Fig. 20. After the computation of F_4, students are asked to identify the zero-force members. Feedback in Fig. 21 guides this task. Finally, the students are asked to compute the remaining member forces (Fig. 22) and color code the result (Fig. 23).

References

Holzer, S. M. and R. H. Andruet, "Students Developing Concepts in Statics," *1998 ASEE Annual Conference and Exposition*, Seattle Washington, June 28 – July 1 (1998)

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Kolb, D., *Experiential Learning,* Prentice Hall, Englewood Cliffs, NJ (1984)

Lochhead, J., "Teaching Analytical Reasoning Through Thinking Aloud Pair Problem Solving," in James E. Stice, Ed., *Teaching Thinking Through Problem Solving,* New Directions for Teaching and Learning, No. 30, Jossey-Bass, San Francisco (1987)

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Stice, J. E., "Using Kolb's Learning Cycle to Improve Student Learning," *Engineering Education,* 77 (5), February (1987)

Acknowledgment

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Figure 2. Trusses

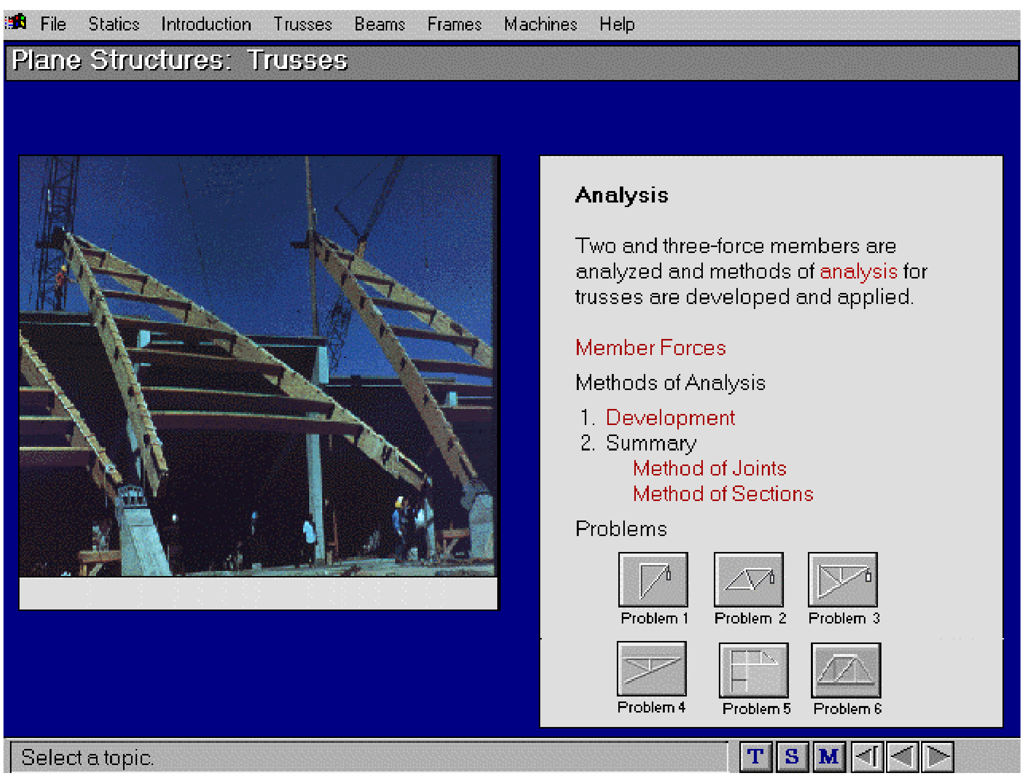

Figure 3. Analysis of Trusses

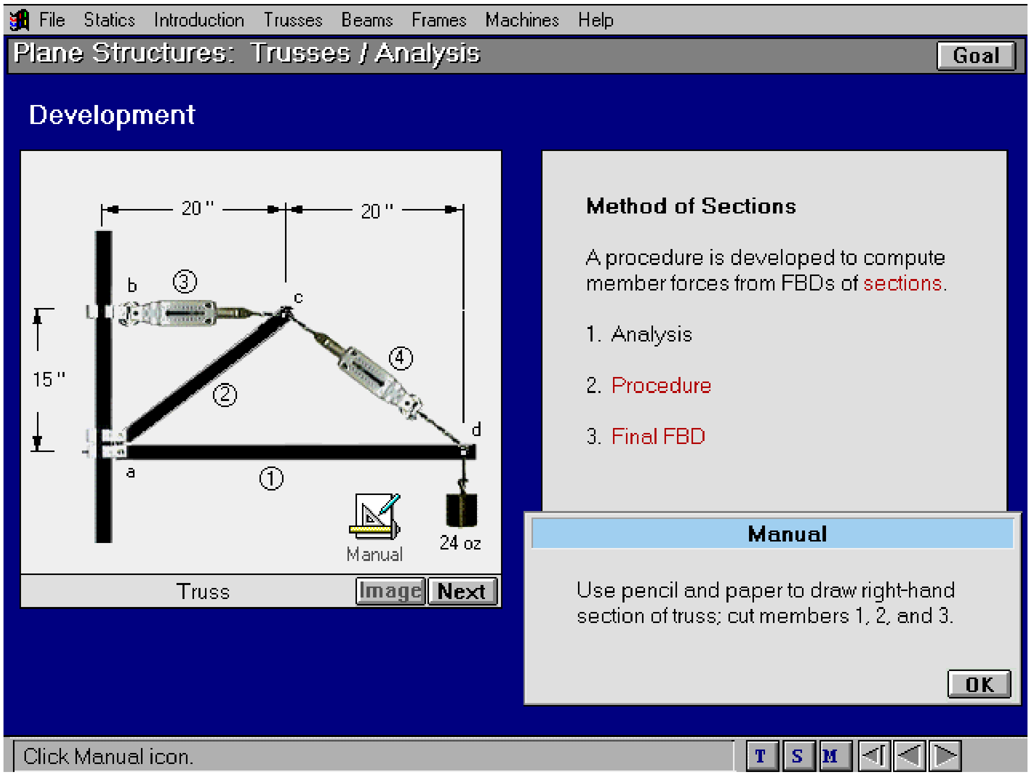

Figure 4. Development of Method of Sections

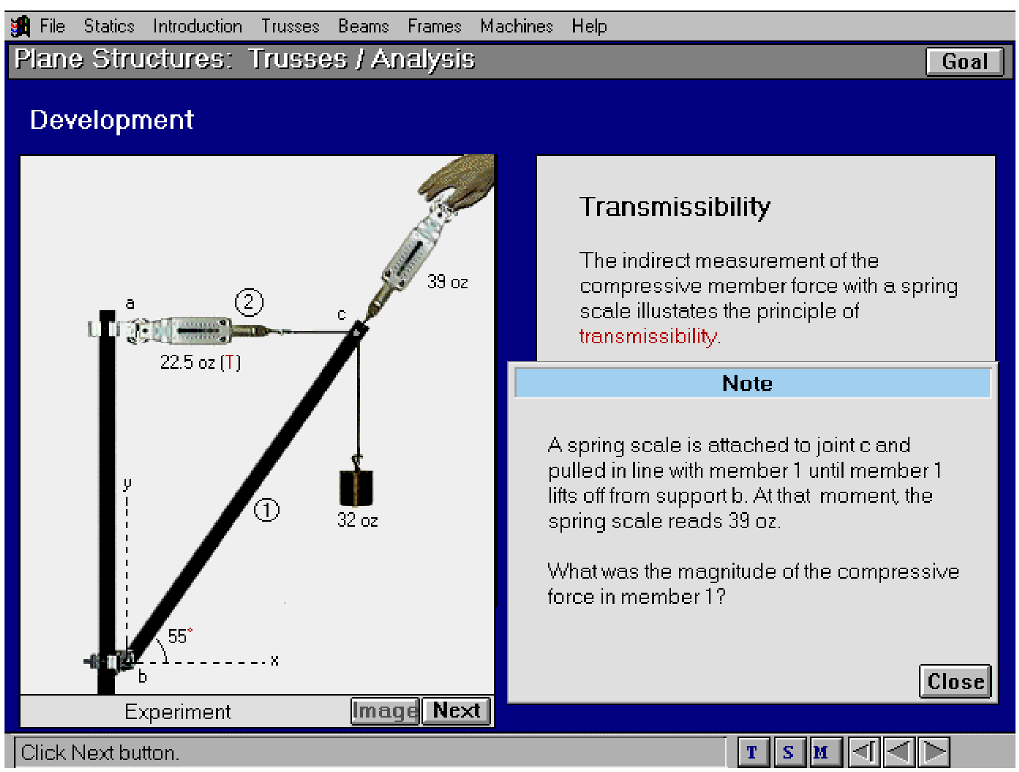

Figure 5. Measuring Compressive Forces

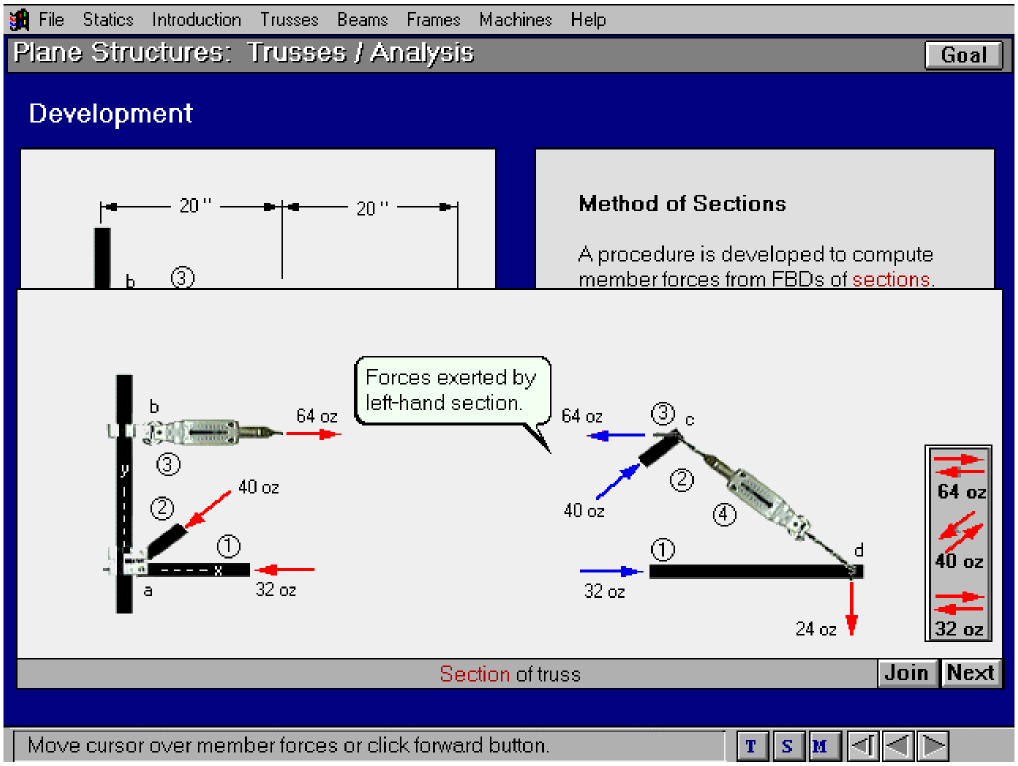

Figure 6. Results of Analysis

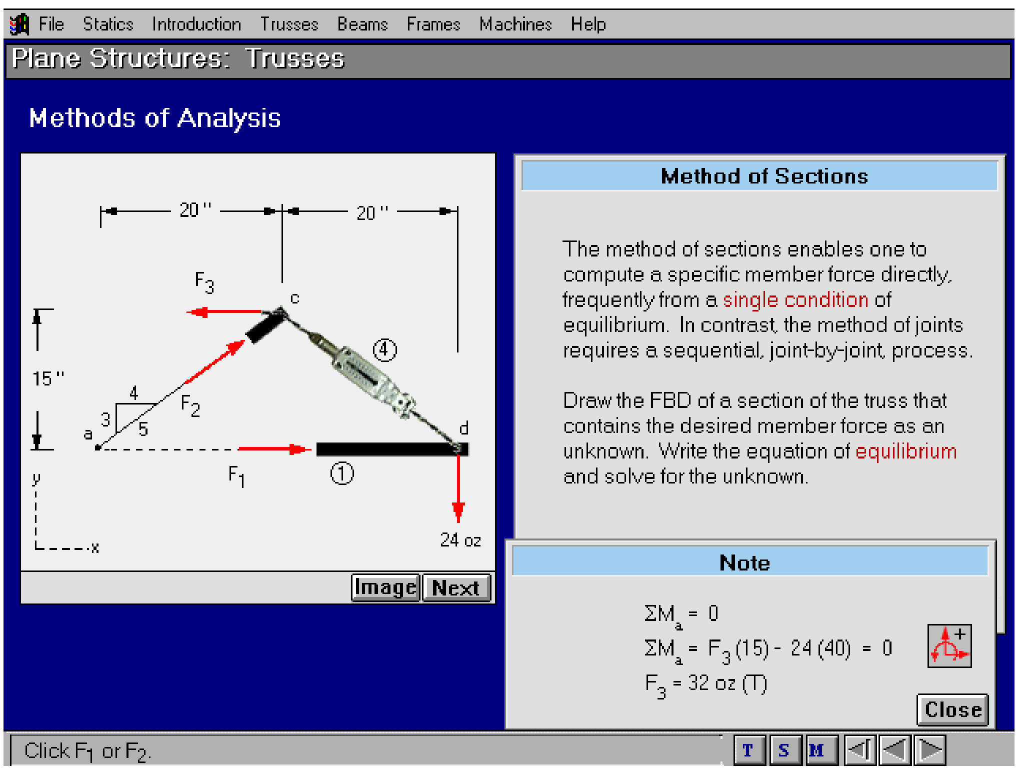

Figure 7. Method of Sections

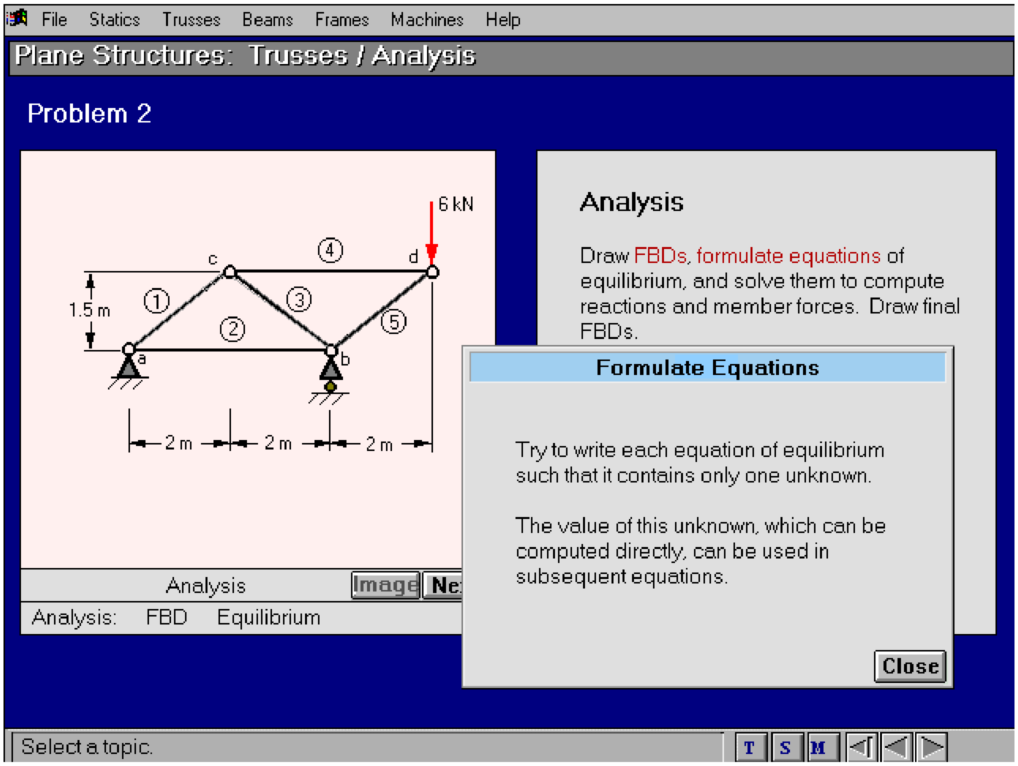

Figure 8. Analysis of Simple Truss

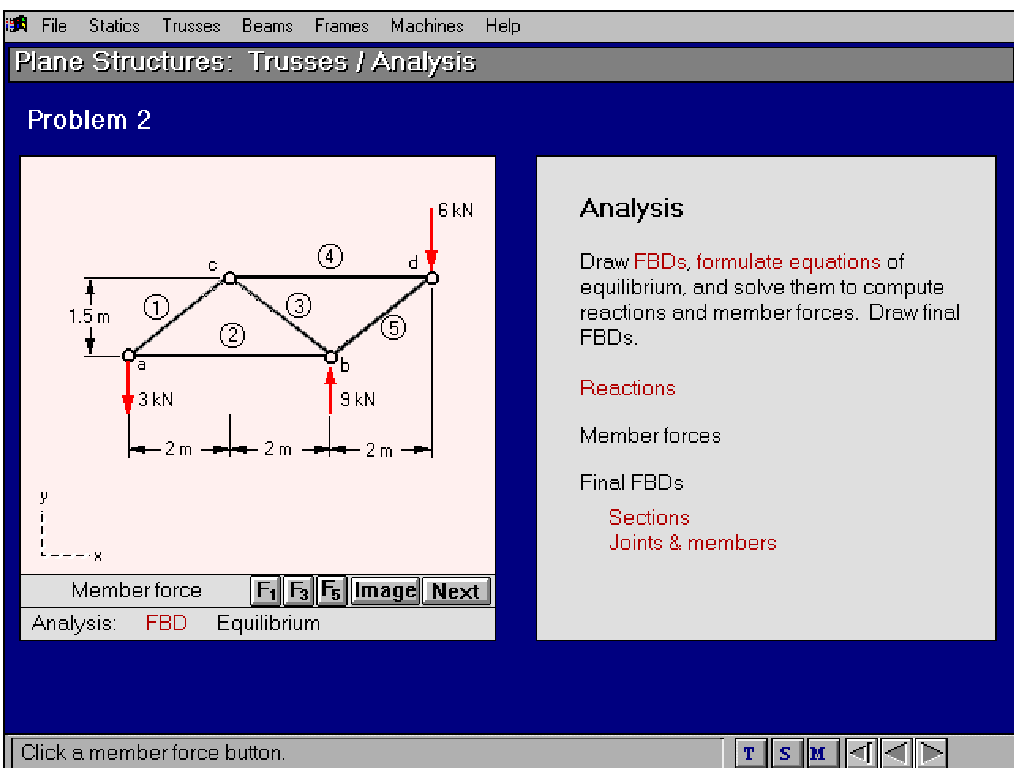

Figure 9. Selection of Member Force

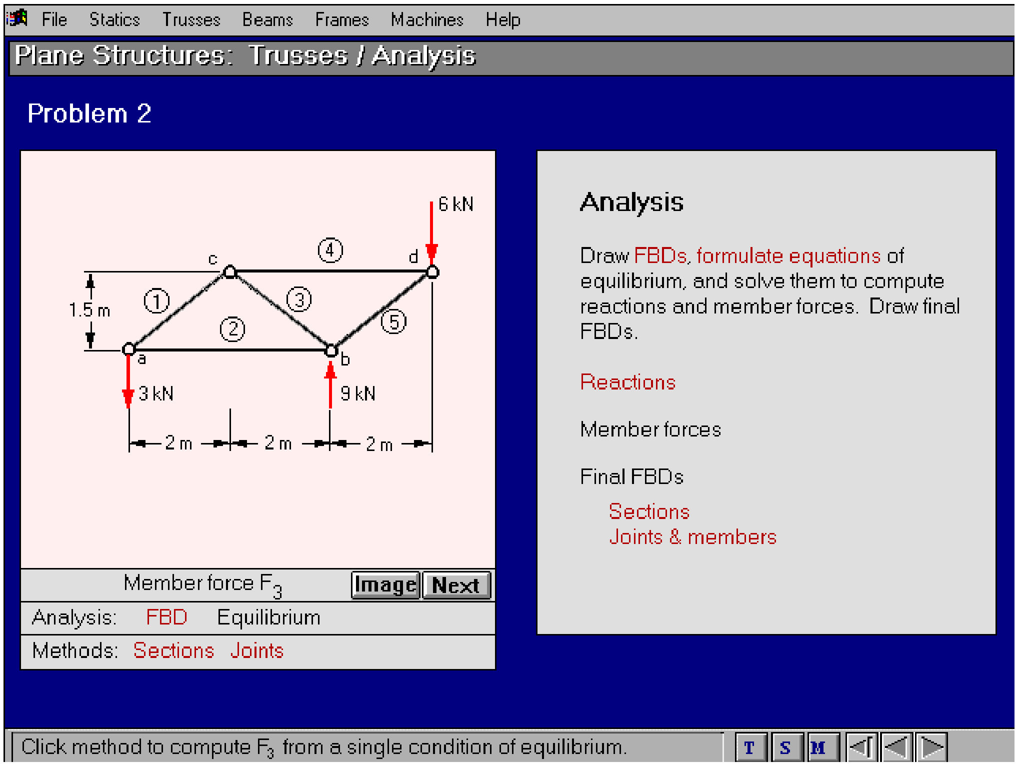

Figure 10. Selection of Analysis Method

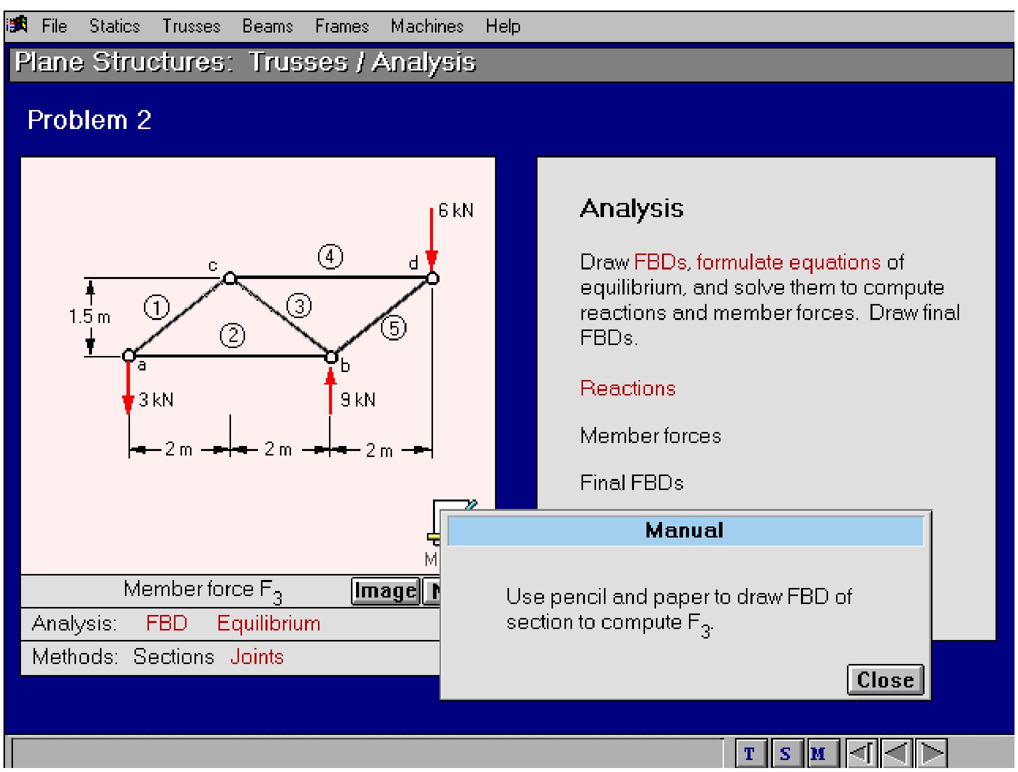

Figure 11. Pencil and Paper Activity

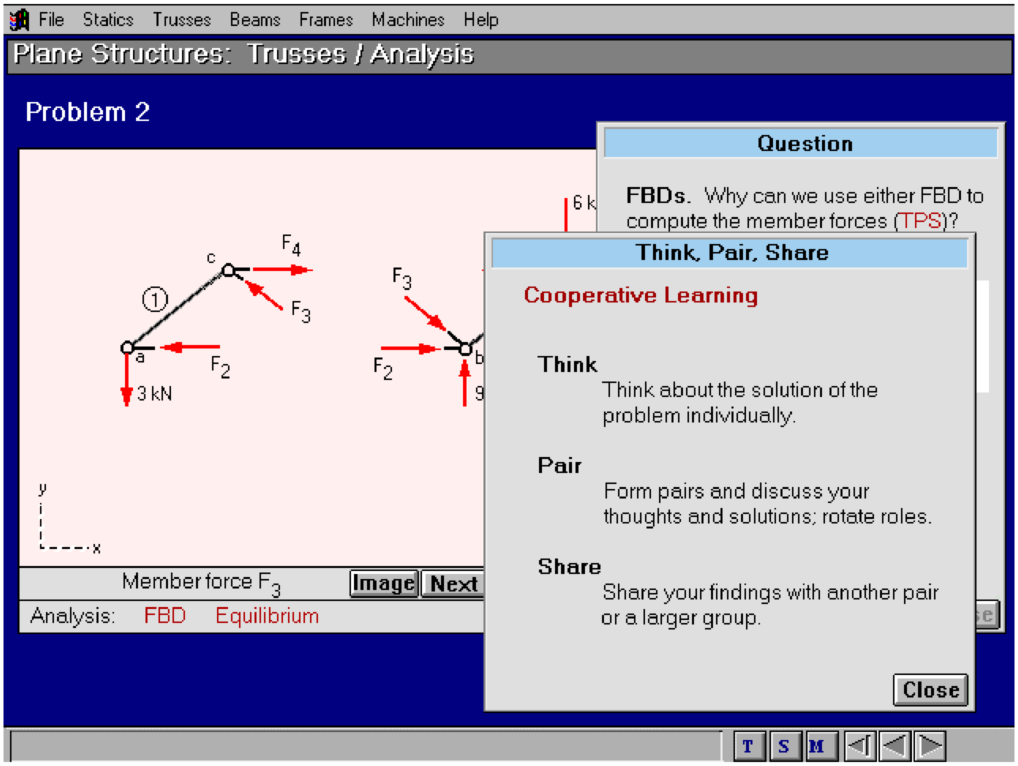

Figure 12. Choice of Section

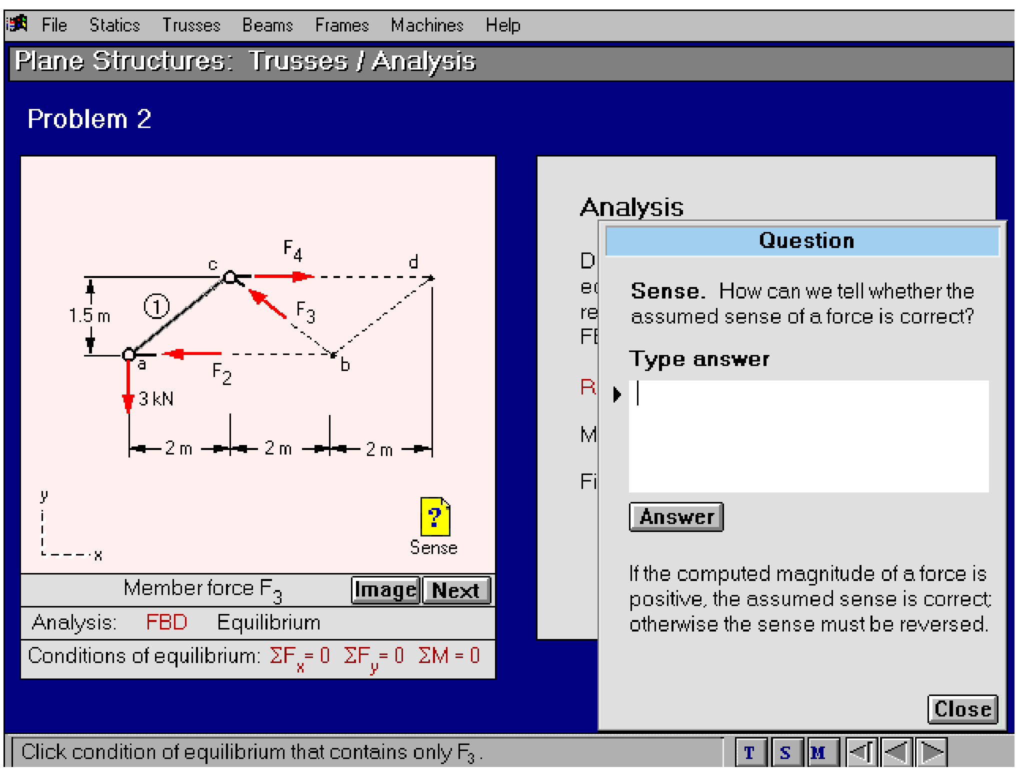

Figure 13. Choice of Sense

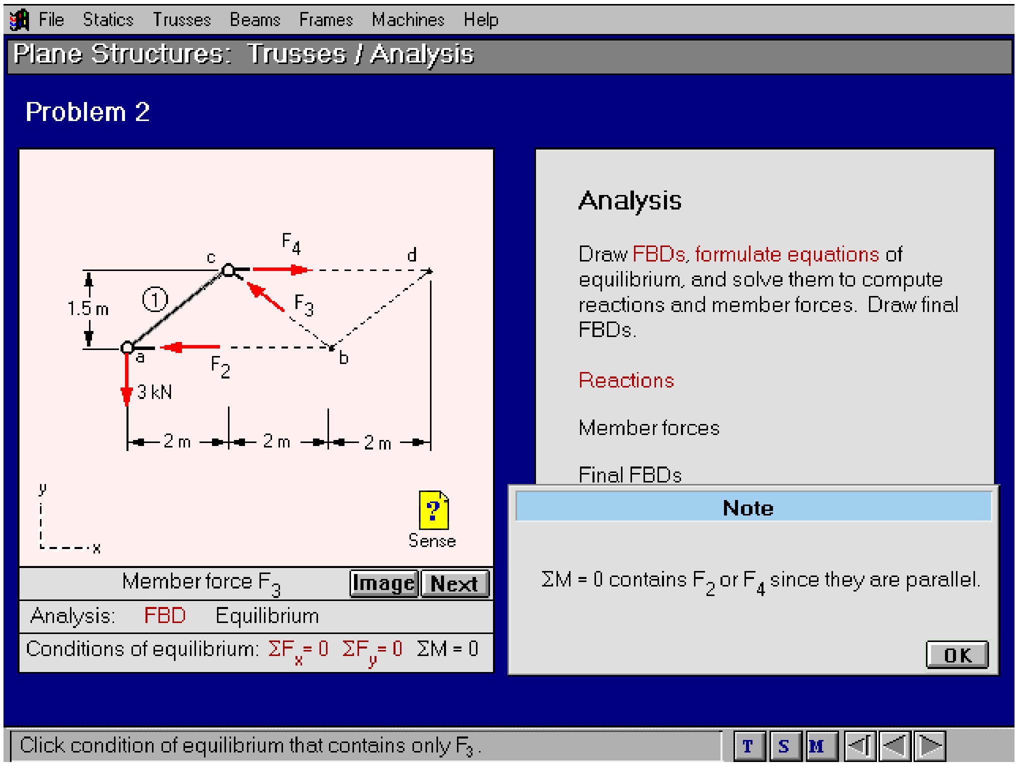

Figure 14. Choice of Equilibrium Condition

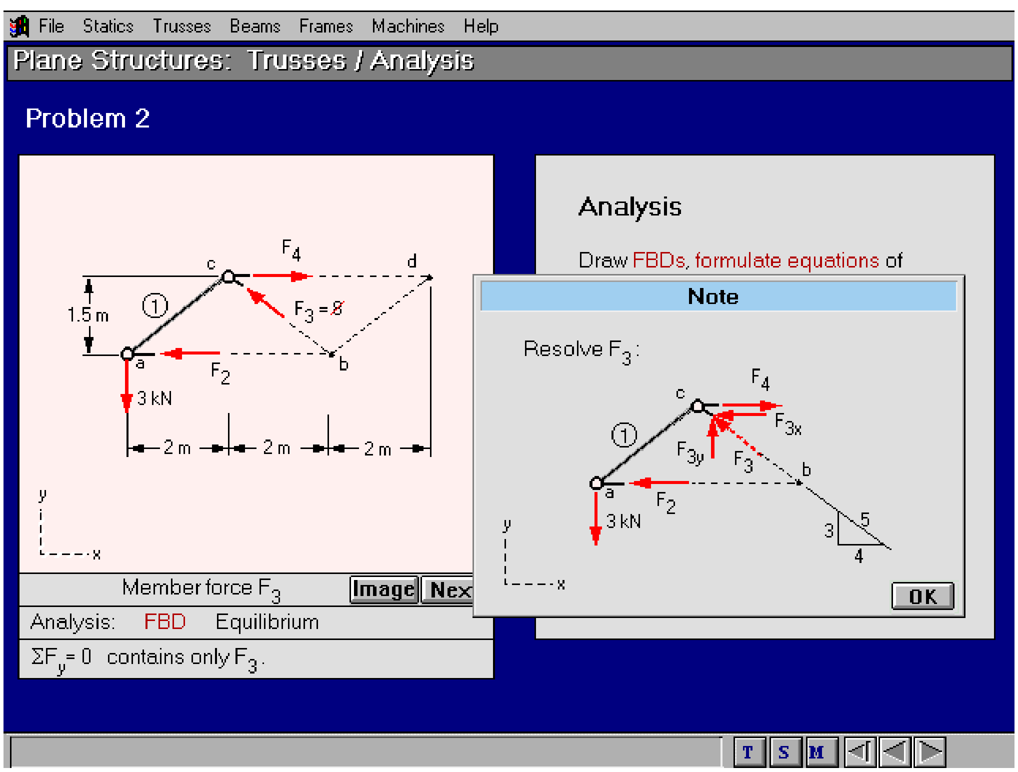

Figure 15. Error Message

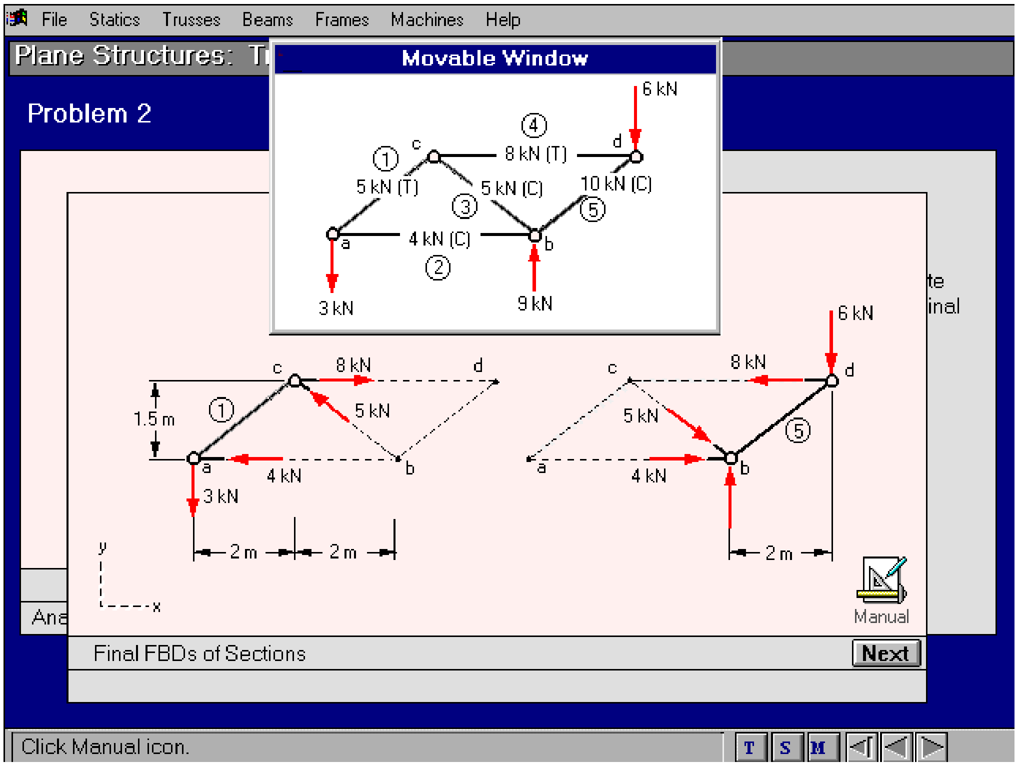

Figure 16. Final Free-Body Diagrams

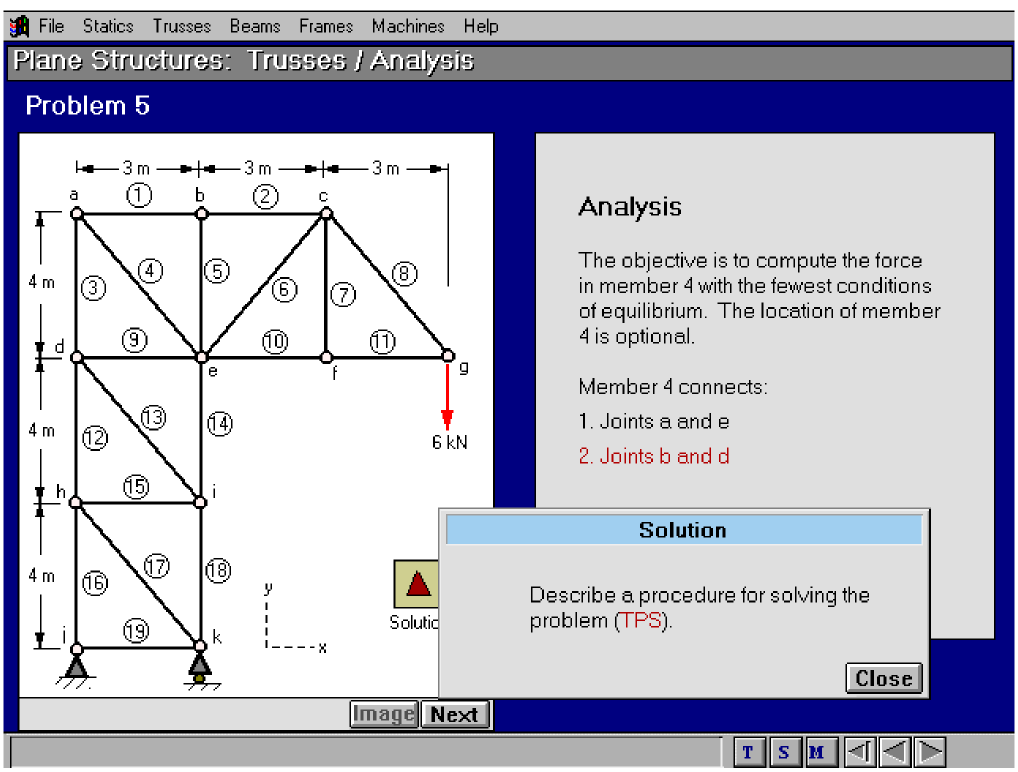

Figure 17. Analysis of Complex Truss

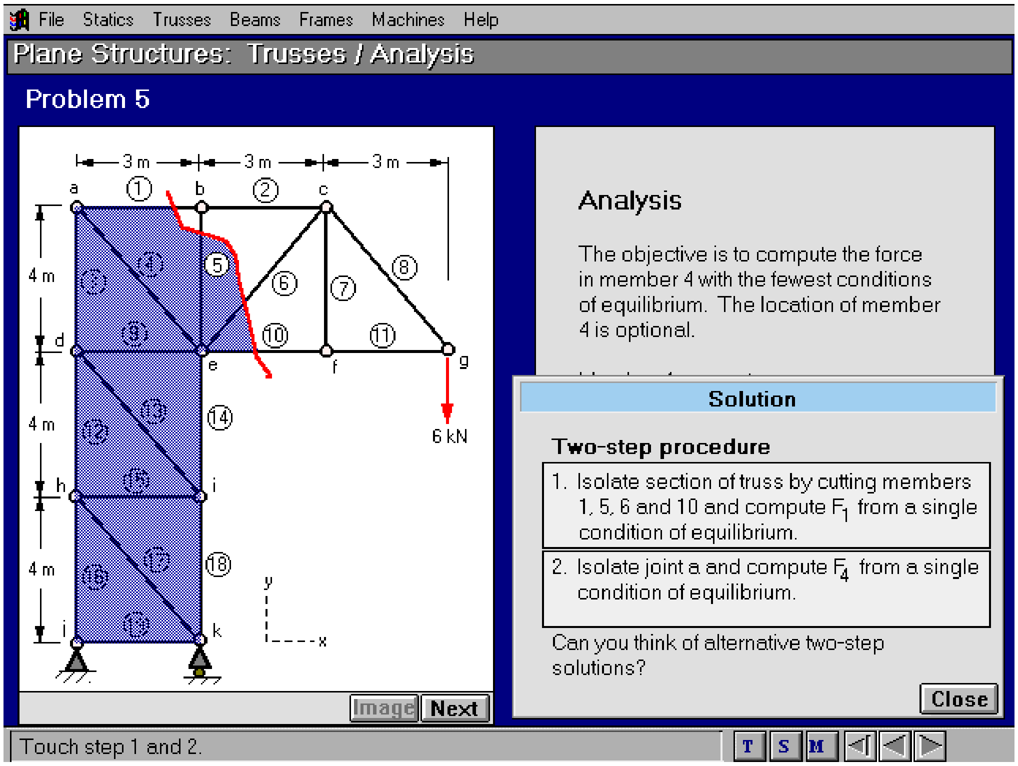

Figure 18. Procedure for F_1

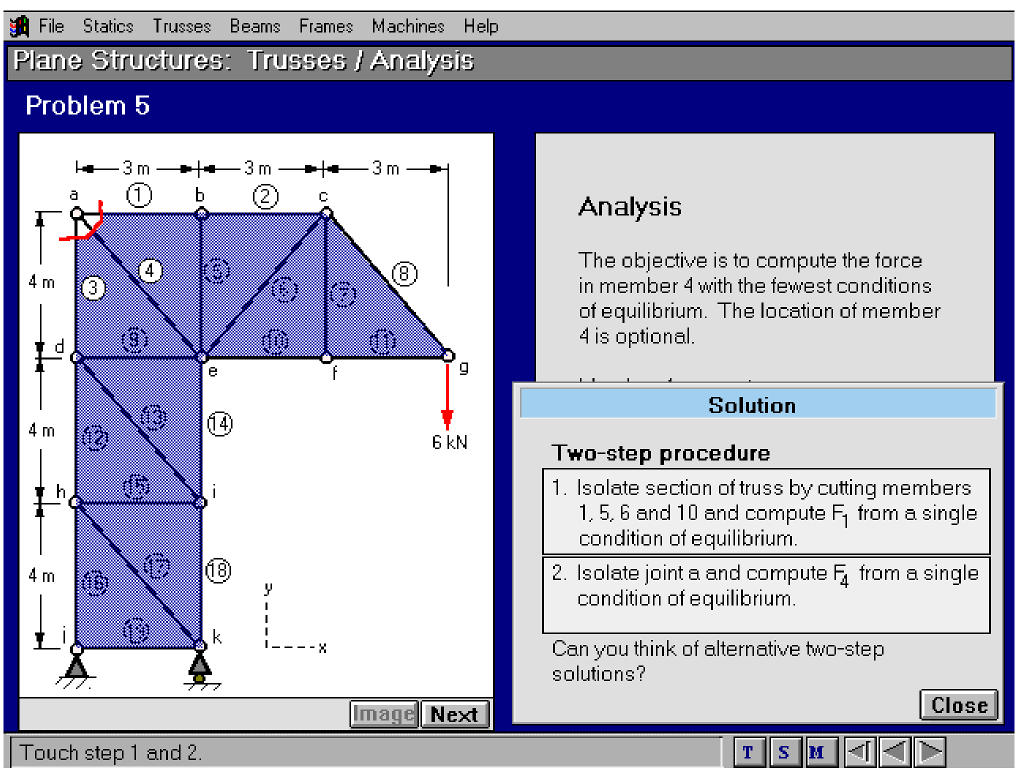

Figure 19. Procedure for F_4

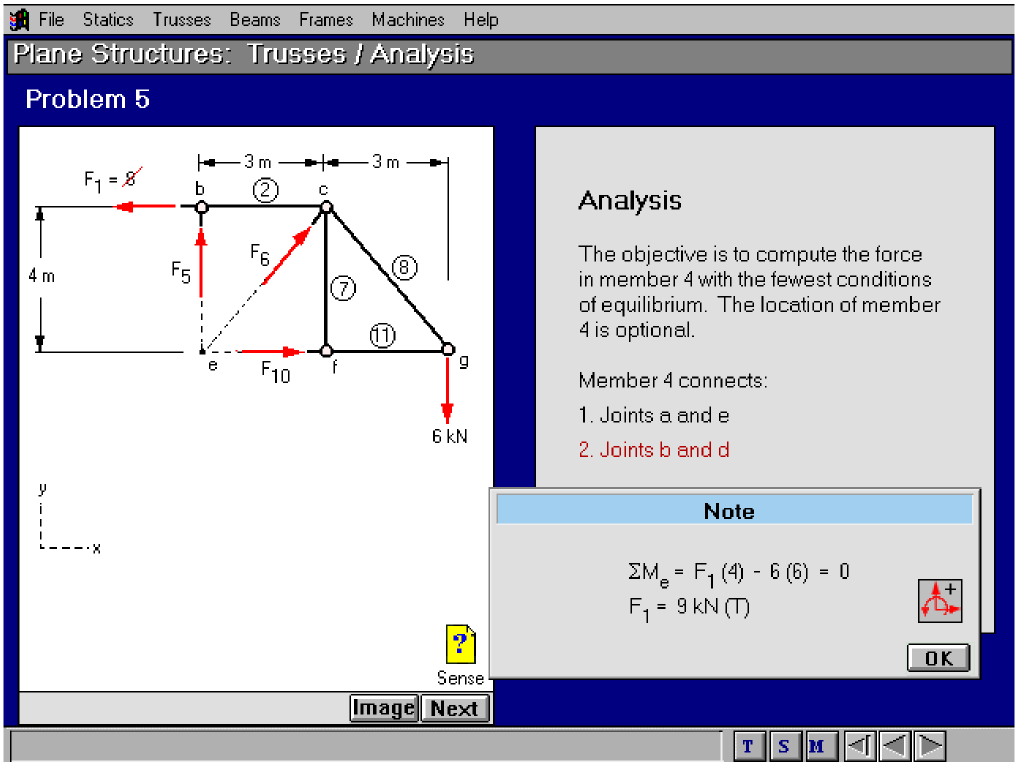

Figure 20. Computation of F_1

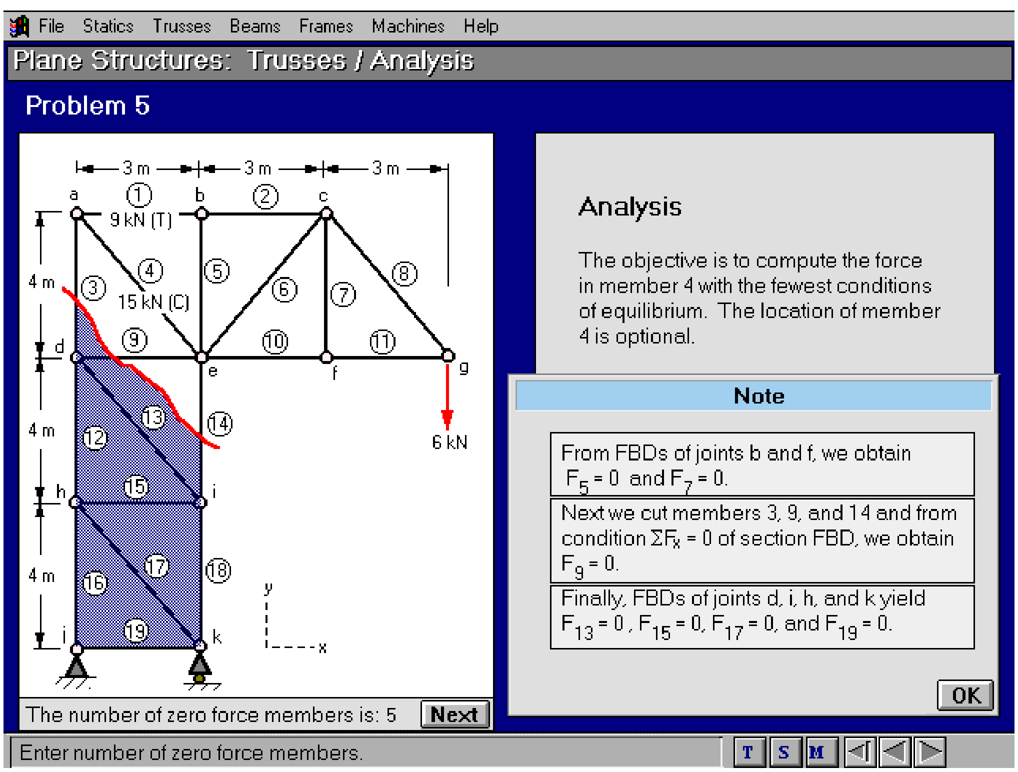

Figure 21. Zero-Force Members

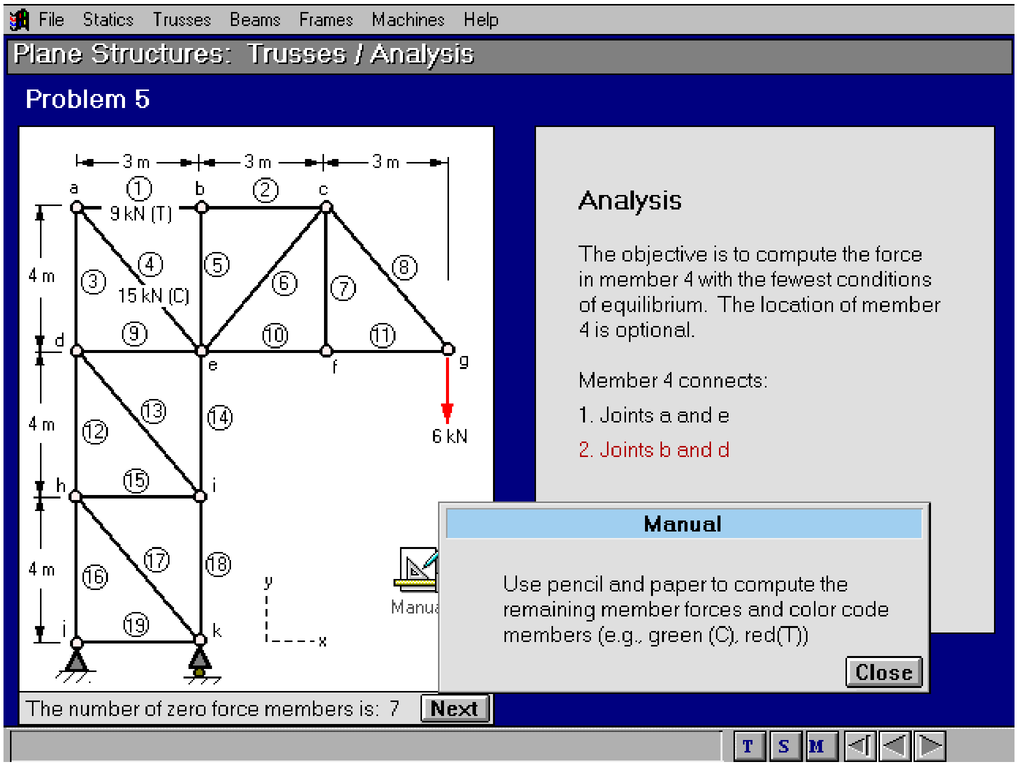

Figure 22. Remaining Member Forces

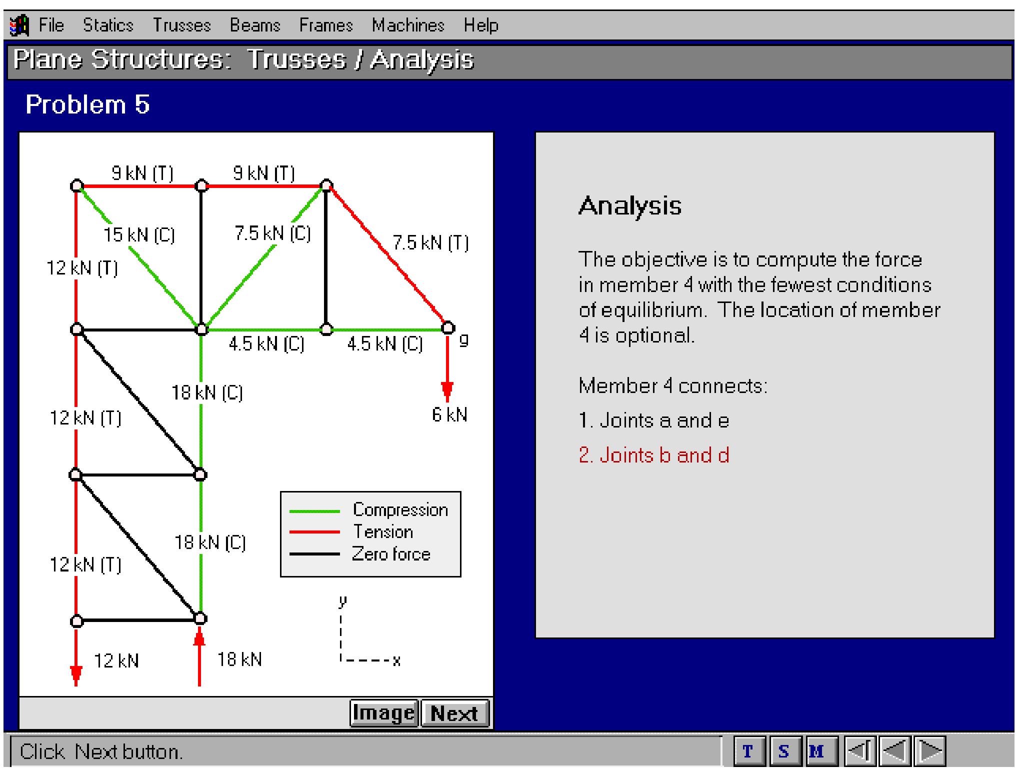

Figure 23. Color-Coded Member Forces