Learning Statics with Multimedia

Samruam Tongtoe[1] and Siegfried Holzer[2]

Abstract

We are developing a learning environment in the subjected area of statics and mechanics of materials 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 5 Attain (1999) to develop the multimedia program. The multimedia modules reflect the experiential learning modes: The inductive approach, starting with concrete experiences, is used to help students discover and develop concepts, principles, and methods of analysis; the deductive approach, starting with concepts, principles, and procedures, provides a quick review and guidance in the solution of problems.

Learning Environment

The principal elements of our learning environment are experiential and cooperative learning. Team work tends to provide students with a variety of benefits which include active involvement, enhanced performance, learning skills, interpersonal skills, and self-esteem and it creates a learning community (Gardiner, 1996). Moreover, "Team learning is vital because teams, not individuals, are the fundamental learning unit in modern organizations" (Senge, 1990). Experiential learning (Kolb, 1984) focuses on the central role that experience plays in the learning process, where "concepts are derived and continuously modified by experience." Kolb (1984, p. 21) defines experiential learning as "a holistic integrative perspective on learning that combines experience, perception, cognition, and behavior." This interconnectedness is central to holistic learning (Miller, 1993).

The multimedia program is designed to engage students actively in learning through frequent questions, incremental feedback, connections to related topics and existing structures, and teamwork. We have utilized the program extensively throughout the course in both of our CIVL 202 Statics sections at The Citadel in the Spring semester 2000. By integrating the multimedia program into the course, students seemed to grasp concepts very quickly, especially in the analysis of trusses. In general, the program facilitated student learning in the various phases of problem solving: modeling, construction of free-body diagrams, formulation and solution of equilibrium equations, and interpretation of results.

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[1] Assistant Professor of Civil and Environmental Engineering, The Citadel, Charleston, SC 29409.

[2] Alumni Distinguished Professor of Civil and Environmental Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.

Experiential Learning

"Learning is a process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 38). The two fundamental activities of learning are grasping and transforming experience (Fig. 1).

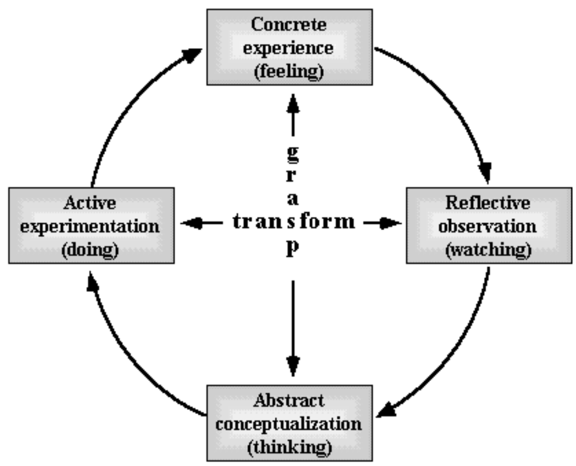

Figure 1. Experiential Learning Model (Kolb, 1984, p. 42)

There are two opposite modes of grasping, directly through the senses (concrete experience) or indirectly in symbolic form (abstract conceptualization). Similarly there are two distinct ways of transforming experience, by reflection or action. The complete process is a four-stage cycle (Fig. 1) of four adaptive learning modes. The active involvement of students through all four learning modes helps develop higher-order skills (Kolb, 1984). A detailed description of these learning modes (type of learners) with suggestions for writing activities, "a means to think and learn," is presented by Sharp, et al. (1997).

Cooperative Learning

Cooperative learning is a structured learning strategy in which small groups of students work toward a common goal (Cooper, et al., 1994). Extensive research, initiated in the late 1800s, has demonstrated significant advantages of cooperative learning over competitive and individualistic learning in various learning characteristics; these include (Johnson et al., 1991): high-level reasoning; generation of new ideas and solutions; motivation for learning; personal responsibility; and student retention.

We have been experimenting with some structures and have found **think-pair-share (TPS)** (Lyman, 1987; Habel, 1996) and variations of pair activities effective in the classroom: Students **think** about a problem individually to organize their thoughts; they form **pairs** to share and discuss their solutions; they **share** and discuss their findings with another pair or a larger group. Another pair activity, specifically designed for problem solving, is called **thinking aloud pair problem solving (TAPPS)** (Lochhead, 1987). Each pair is divided into a problem solver and a listener, each with specific instructions. Their roles are reversed after every problem but not during a problem. Aside from being an effective cooperative learning tool, **TAPPS** facilitates the development of communication, listening, and team learning skills. If a team struggles, try **TAPPS**. The students' active involvement is essential in developing problem solving skills (Woods, et al., 1997).

Computer Lab

Students use the program in the computer lab sessions, where two students share one computer (Fig. 2). A session is generally divided into three parts: (1) we start with short group activities, a warm-up problem, to focus on problems or questions that surfaced in homework, weekly quizzes, or minute papers; (2) this is followed by mini lectures (10-15 minutes long) interspersed with cooperative activities; (3) at the end of a session, students are asked to reflect and answer questions about the day's lesson and activities in minute papers (Cross, 1991). Light (1991, p. 36) states: "This extraordinarily simple idea (the one-minute paper) is catching on throughout Harvard. Some experienced professors comment that it is the best example of high payoff for a tiny investment they have ever seen." It provides real-time feedback of student learning and problems and the opportunity to make incremental improvements in the learning environment.

Figure 2. Computer Lab

Multimedia Program

The multimedia program is constructed with Authorware 5 Attain (1999). We are using the program in various ways: (1) to present mini-lectures; (2) to guide student teams in the development of concepts, the solution of problems, and discussions; (3) to provide connections to the students' background and engineering structures; (4) to integrate traditional pencil-and-paper activities; and (5) to preview and review lessons. Students can download the multimedia program from the departmental server at The Citadel to their computers, and they use it to review lessons and prepare for tests. The program can be obtained free of charge from Holzer at holzer@vt.edu.

Navigation tools in the multimedia program (Fig. 3) include: pull-down menus, hotwords (in red), local buttons (e.g., Next), and global buttons (e.g., Previous menu in command bar).

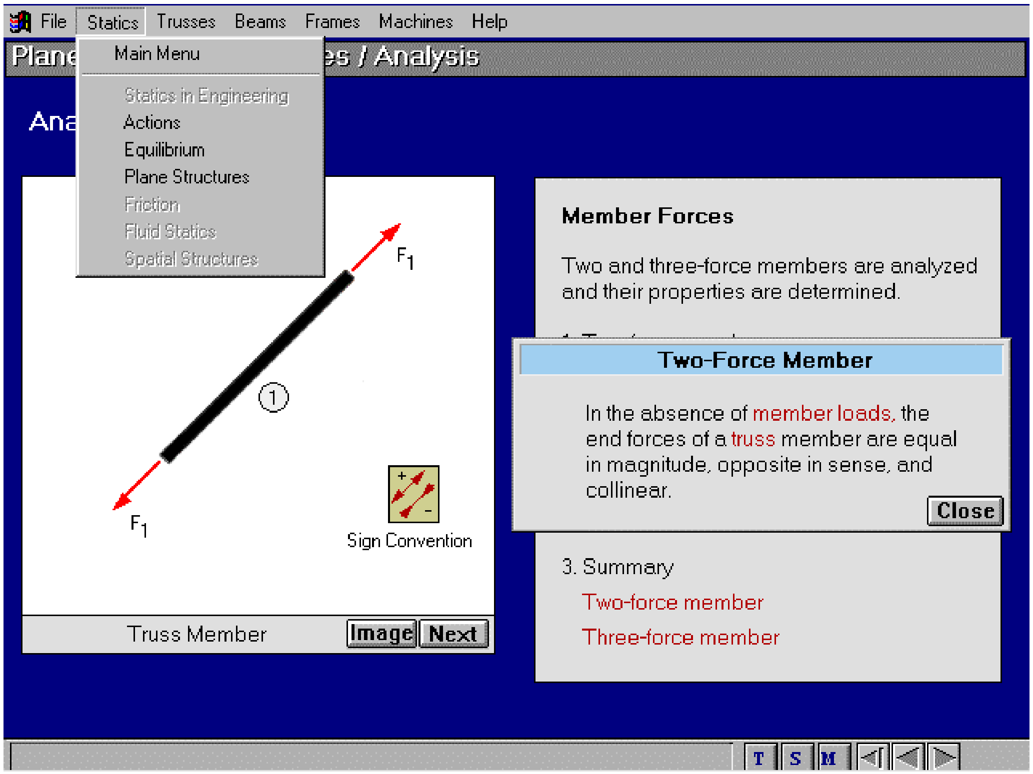

Figure 3. Navigation Tools

Samples of Multimedia Modules

Samples of multimedia modules are presented to illustrate some learning activities. The samples include vector components and free-body diagrams, plane trusses, and shear and moment diagrams. In all of these activities, students also experiment with simple physical models.

Vector Components and Free-Body Diagrams

One of difficulties students face in statics is to link abstract concepts, such as free-body diagrams and vectors, with concrete experiences. The simple physical model in Fig. 4 is one example that facilitates this tasks: (1) students hold the spring scales to feel the tensions in the strings; (2) they draw a free-body diagram of point O, where the strings are concurrent; (3) they compute the forces in the strings from conditions of equilibrium; and (4) they compare the results with tensions recorded by the spring scales.

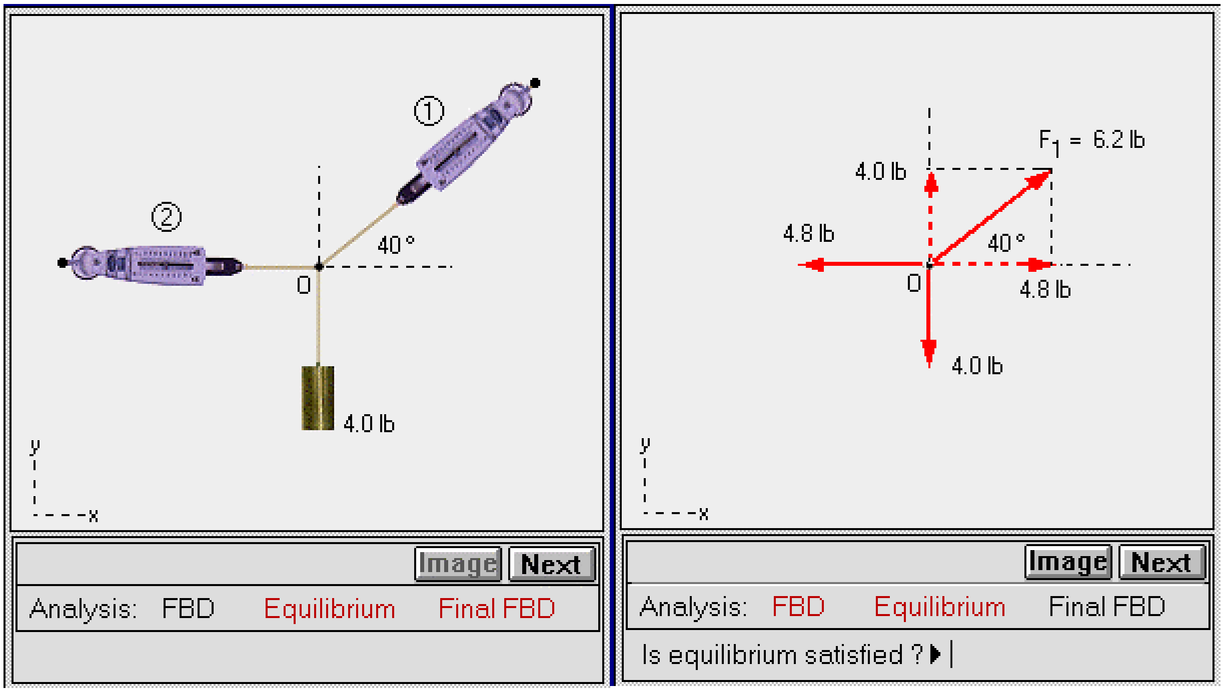

Figure 4. Free Body Diagram

Plane Trusses

Active learning is promoted by: linking the new with the old (analysis of physical truss models early in the course); teamwork (TPS); and connections to real truss structures. We start learning about trusses by exploring images of existing truss structures. The objective is to identify their common characteristics. Students observe that trusses are composed of triangular units. They use physical models of pin-connected assemblies composed of three and four members to discover that three-member assemblies are stable while four-member assemblies form a mechanism. Since the joints have negligible rotational stiffness, members transmit essentially compressive and tensile forces. The analysis of trusses (Fig. 5) 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.** In **member forces,** we use the 3-step analysis process (FBD, Equilibrium, Final FBD) to guide teams of students in the development of two- and three-force members. A summary of the results facilitates a quick review of the properties of two- and three-force members (Fig. 6).

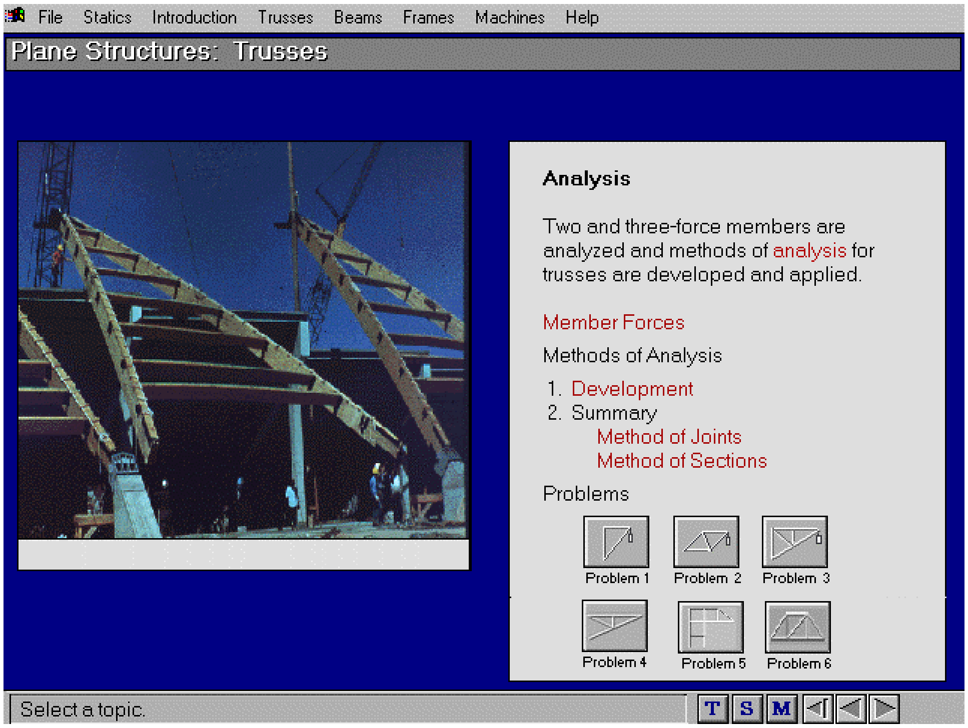

Figure 5. Analysis of Trusses

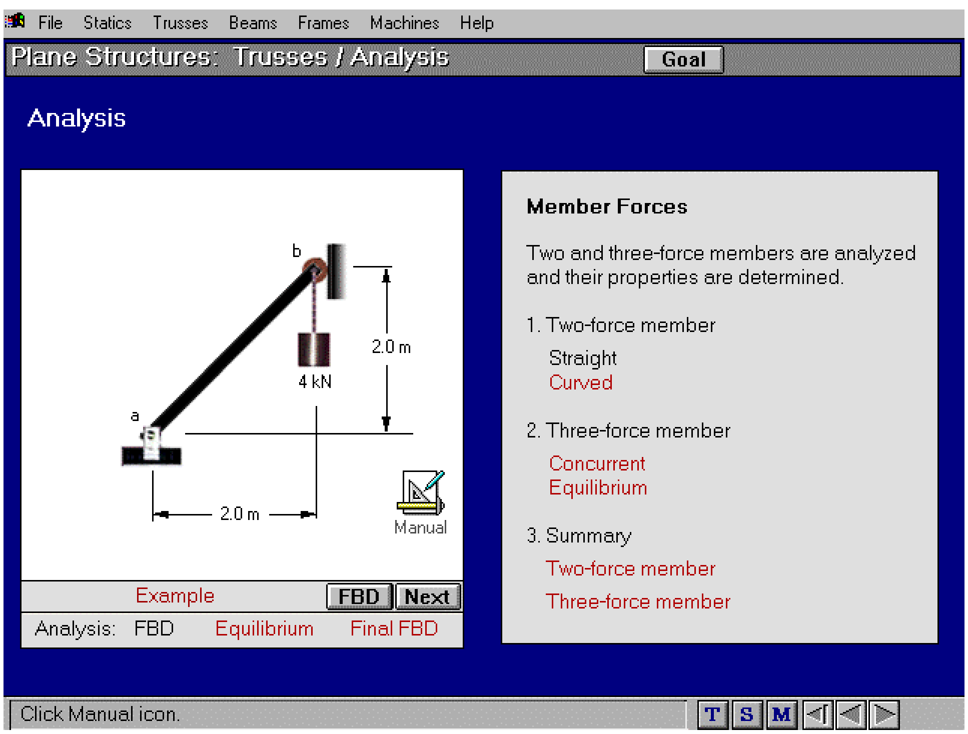

Figure 6. Member Forces

Shear and Moment Diagrams

Figures 7- 8 illustrate an inductive approach to develop methods for drawing shear and moment diagrams (Holzer and Andruet, 2000). The method of sections (Fig. 7) is defined after some exploration and linked with truss analysis; forming connections facilitates learning. The objective, reflected in Figure 7, is to write the functions V(x) and M(x) for the domains between concentrated forces and to graph them.

The method of integration is first developed for a specific beam segment. Specifically, the shear-load and moment-shear relations are obtained from conditions of equilibrium in Figure 8, and relations for the slopes of shear and moment diagrams are inferred from specific examples. Only after students have developed the method of integration and applied it to simple problems are the general differential equilibrium equations derived and integrated to verify the procedure.

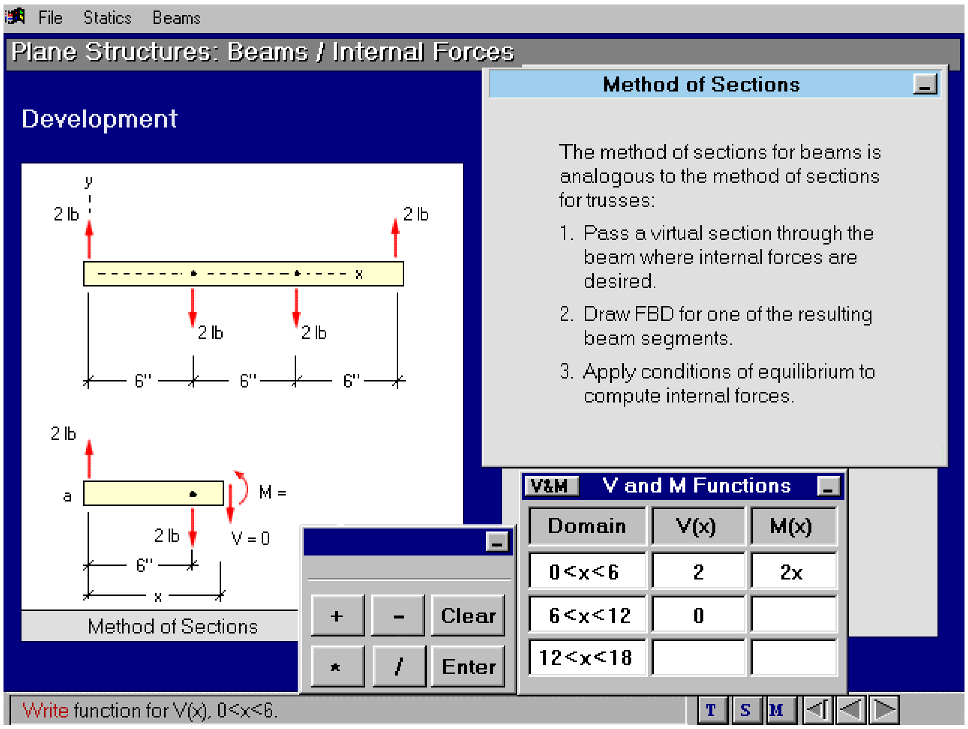

Figure 7. Method of Sections

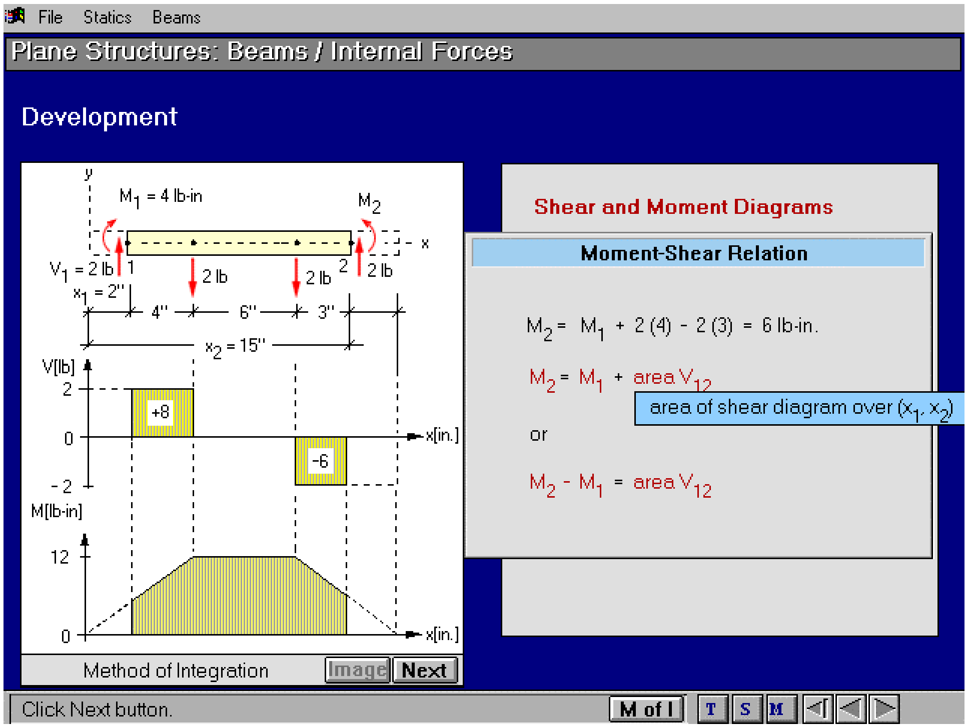

Figure 8. Method of Integration

Learning Outcomes

Assessment tools (Angelo and Cross 1993) of students' learning in our class include: pretest, minute papers, weekly quizzes, examinations, and student evaluations. The multimedia program was used by a group of 26 students at The Citadel. To evaluate the multimedia program, students completed a questionnaire (Table 1) with the following response scale: 1 (disagree), 2 (tend to agree), 3 (tend to agree), 4 (agree). The student's response indicates that the program facilitated learning.

The following excerpts from student evaluations at The Citadel provide some insight into their learning experiences:

- *The computer lab sessions helped me stay awake. I liked to work on the program with my partner. We helped each other to complete the given task.*
- *I liked the program a lot. It was hard to follow examples in the textbook. It was really easy to follow examples in the program.*
- *I downloaded the program and used it a lot to learn and review the materials.*
- *The multimedia program challenged me to think.*
- *The multimedia program offered real world problems and applications.*

Table 1. Multimedia Program Student Questionnaire

Statement	**Mean Response**	**Percent of students who agree or tend to agree**
1. Objectives: The "Goals" in the program clearly state the objectives of specific learning modules.	3.6	100
2. Inductive approach: The development of concepts and principles and methods of analysis from concrete examples facilitates learning.	3.8	100
3. Deductive approach: The summaries of concepts, principles, and methods of analysis provide the opportunity for quick reviews and reinforcements.	3.7	100
4. Navigation: It is easy to move around in the program and know where you are.	3.3	85
5. I would have liked to use the program more in class.	3.5	92
6. I would have liked to use the program more outside of class.	3.2	77

Student evaluations of in the multimedia statics program at Virginia Tech are presented by Holzer and Andruet (2000). They also discuss how to achieve a good balance among the various activities in this rich learning environment, particularly for students who are not highly motivated or skilled learners.

The inductive approach leading to the discovery and development of concepts requires time and patience. It may seem inefficient as compared to the traditional approach, but it is not if efficiency is measured in terms of student learning (Barr and Tagg, 1995).

The potential impact of an effective learning environment in statics is significant. For many students the traditional statics class is an unfriendly environment. We cover too much materials in abstract form, at a very fast pace, and provide little opportunity to learn what engineering is and how it fits into society at large.

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Samruam Tongtoe

Samruam Tongtoe is an assistant professor in the Department of Civil and Environmental Engineering at The Citadel in Charleston, South Carolina. He received his undergraduate degree from The Citadel in 1985, and his M.S. and Ph.D. degrees from Virginia Tech in 1987 and 1997. His areas of interest include finite element analysis and multimedia development. He currently serves as Faculty Advisor of The Citadel's Student Chapter of the American Society of Civil Engineers.

Siegfried Holzer

Siegfried M. Holzer, Alumni Distinguished Professor of Civil Engineering at Virginia Tech, is involved in faculty development programs and active learning environments. He is leading the adaptation and implementation of the SUCCEED model for undergraduate engineering education at Virginia Tech (holzer@vt.edu). SUCCEED is a National Science Foundation coalition.