

Incorporating Technology into the Traditional Engineering Mechanics Lecture

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Abstract: The advancement of information technology has provided faculty with many opportunities to adopt and incorporate it into traditional classroom teaching. However, the new technology is not always better. For many topics, the best strategy is still the traditional chalk-and-talk lecture. There are three critical requirements in getting new technology adopted on a large scale.

1. The new technology should be able to facilitate student learning and understanding. It should be better than a traditional lecture.
2. The new technology should be easy to use. Learning to use the technology should not create excessive work for the faculty member. Class preparation should take approximately the same amount of time as for a traditional lecture.
3. The new technology should be reliable and convenient.

Dr. Carroll is currently using a technological method for teaching engineering mechanics courses that meets the criteria listed above. A key component to the method is that the faculty member projects complex figures on the board and then uses chalk (or markers or a smart board or a tablet) to modify the figures. This teaching method blends the traditional lecture with the new technology, utilizing the new technology to improve the quality of the traditional lecture. From the instructor's perspective, preparing the lecture takes approximately the same amount of time as preparing a traditional lecture. The use of technology has been well received by the students.

Introduction

The chalkboard is a very effective tool for teaching. It frees us from our short term memory. With the chalkboard, the teacher can put several ideas up at once, and show how the ideas are related, or how one idea flows from another. The students can watch ideas and arguments develop in a logical manner, and the process can be paused and restarted to be sure the students understand and keep up with the lecture. Figures can be drawn to utilize our visual learning capabilities. The chalkboard is useful in teaching all subjects, but is especially indispensable in teaching mathematics and science. Following is a quote from Samuel May:

"... in the winter of 1813 & '14 , during my first College vacations, I attended a mathematical school kept in Boston by the Rev. Francis Xavier Brosius . . . On entering his room, we were struck at the appearance of an ample Black Board suspended on the wall, with lumps of chalk on a ledge below, and cloths hanging at either side. I had never heard of such a thing before. There it was—forty-two years ago—that I first saw what now I trust is considered indispensable in

every school—the Black Board—and there that I first witnessed the process of analytical and inductive teaching.” [Samuel J. May 1855] (Anderson, 2004)

The chalkboard is a very powerful tool for teaching engineering mechanics courses. Students can watch the derivations and example problems evolve and develop on the board in a logical sequence. They can copy the figures and text as notes, using the "see it, hear it, write it down" method of learning. The strengths of the chalkboard are that it is a very versatile tool, it is very reliable, it is inexpensive, and it doesn't require the faculty member to learn a complex software package.

The disadvantage of the chalkboard in teaching engineering mechanics courses lies primarily in developing three dimensional figures and drawings of gears or other complex objects. It is very difficult to draw a good figure in a reasonable amount of class time. In most cases, the faculty member can practice in the office and draw a decent figure on the chalkboard, but the students have not had the opportunity to practice, so the figures in their notes are atrocious. This makes their notes of questionable value. As we look to technology to improve the traditional lecture, the focus should be on using technology to generate better figures in the lecture and in the student's notes.

Goals

The primary goal is to improve student learning in the statics and mechanics of materials classes. Research shows that information technology can affect learning in at least two ways: it can deliver some routine activities more efficiently and it can facilitate engaging, participatory activities for students (Niederman and Rollier, 2001).

We wish to use technology to enhance the traditional chalk and talk lecture method, not replace it. Specifically we wish to improve the quality of the lecture and the quality of the notes taken by the students during the lecture. As students learn more during the lecture and take better quality notes, they will be more productive during their homework and study time. These goals must be accomplished subject to the constraints listed below.

1. The improvements in student learning cannot require significantly more class preparation time by the faculty than a traditional chalk and talk lecture. Faculty are busy, often being asked to "do more with less". Learning improvements that require a large amount of faculty preparation time are not sustainable. Some faculty will put in the extra effort for a while, but in the long term these types of improvements will be discarded.
2. Faculty should not be expected to learn a complex new software package specifically for doing the lecture. The software needs to be intuitive or most faculty will not be willing to take the time to learn to use it.
3. Faculty must be able to prepare lectures only a day or two before the lectures are to be given. It is not realistic to expect faculty to prepare lectures weeks or months in advance.
4. The technology must be reliable and convenient to use.

Incorporating Technology Into the Lecture

Many faculty find drawing three dimensional figures on the board frustrating. It takes a significant amount of class time to draw and dimension the figure, and many of the students in the class will not understand the figure, and will ask for a lot of clarification. If a student does not understand the figure, he/she will not understand the lecture. It is frustrating for teachers and students. Even if the teacher can draw an accurate figure, the students will not be able to duplicate the drawing in their notes, and their notes will be of little use in helping them study. This is an age old problem, and it has always been a barrier preventing many students from understanding some of the more complicated problems in the courses. As computers and projectors have become commonplace in classrooms, it is now possible to help a larger percentage of students break through this barrier and learn to work the more challenging problems. Lecture blanks are prepared for the students so that they will have the high quality graphics in their notes, and can modify the graphics in their notes the same way the teacher modifies the graphic on the board. The students find this process beneficial.

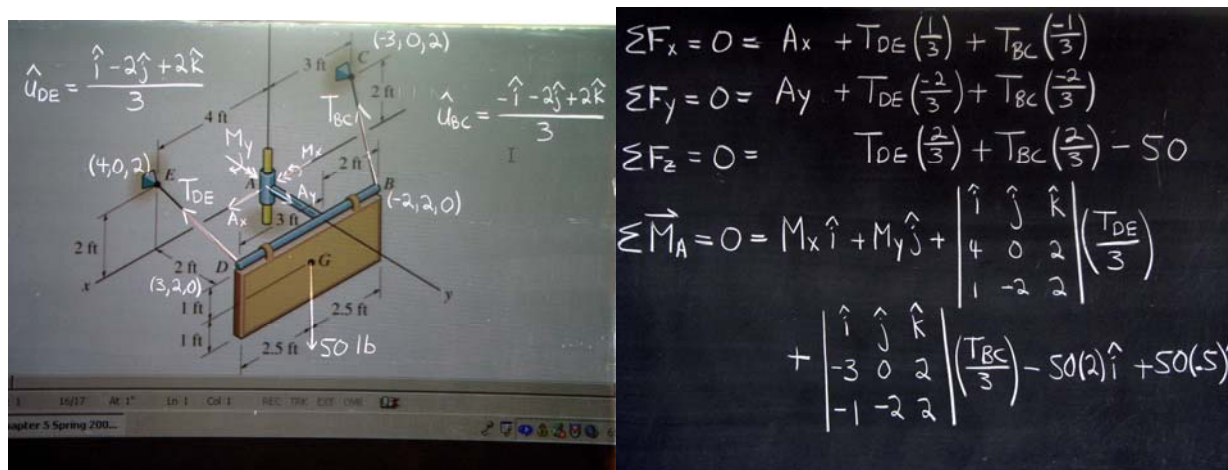


Figure 1. High Quality Graphic and Blackboard Equations

Figure 1 illustrates the lecture process. The figure was projected on the left board to start the process. The teacher discusses the supports and adds the support reactions using chalk. The x-y-z coordinates of the key points are labeled and unit vectors are developed for the cable supports. The equations of equilibrium are developed on the right board and the mathematics to solve the problem will be continued on other boards. As the high quality graphic on the board is modified, the students will modify the high quality graphic in their notes. The equations developed on the right board will be placed under the graphic on their paper. Figure 2 is a copy of the lecture notes, and illustrates the students' notes. The result is a high quality lecture presentation and high quality student notes. The students go through the "see it, hear it, write it down" learning process in a very high quality environment. It is very difficult to work this problem in a traditional chalk and talk lecture because it is not possible to draw a high quality graphic on the board. Even if the faculty member is capable of drawing such an image, most students will not be able to duplicate it in their notes.

Problem 5-82

Determine the tensions in the cables and the components of reaction acting on the smooth collar at A necessary to hold the 50 lb sign in equilibrium. The center of gravity for the sign is at G.

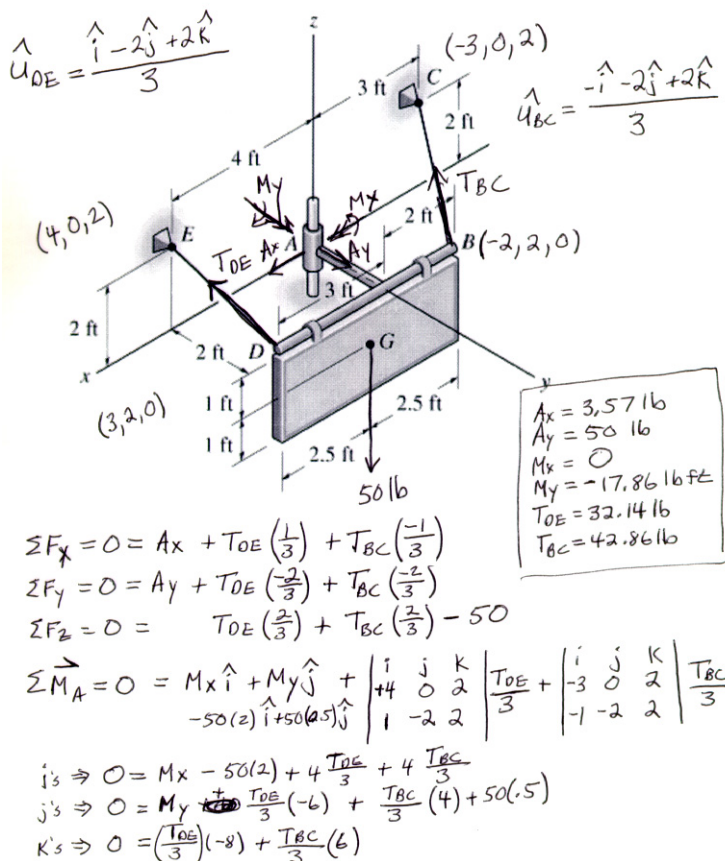


Figure 2. Notes Developed During Class.

Preparing the Lecture

The software used to create the lecture files is Microsoft Word[®], or any word processor. Textbook companies make all of the figures in the text available to faculty, either on a CD or at a web site. For derivations, appropriate figure can be copied and pasted into the Word[®] document, leaving plenty of blank space to develop the derivation by hand. Example problems can be copied and pasted one problem per page so that there will be plenty of space to work out the solution. There will be four or five pages per lecture file, and it takes 15 or 20 minutes to create the lecture file. The file is emailed to the students, or made available to them at a web site. The students print the file, and bring it to class in a binder. The students learn very quickly that they must have the printed notes to keep up in the lecture, so after the first week, virtually all of the students bring the printed notes.

The preparation time for this lecture method is approximately the same as for a traditional chalk and talk lecture. All faculty know how to use web software and a word processor, so no new software must be learned to use this lecture process. The classroom must have a projector that shines on the board and a computer installed in the classroom that is networked so that the faculty member can use the technology conveniently.

During class, the Word[®] document is opened and the zoom factor is adjusted to make the images and text the right size on the board. Only a portion of the page will be projected on the board. Chalk is used to modify the figure as appropriate and develop the mathematics on chalkboards adjacent to the figure. The students follow along taking notes in the note pages that they have brought to class. With this process, less time is spent writing and drawing on the board and more time talking and pausing to allow the students to ask questions. Less class time is spent writing down problem statements and drawing figures, making it possible to work one more example problem in a typical 50 minute lecture than would be possible using the traditional chalk and talk lecture method. The students find this process makes it easier for them to take notes. The quality of their notes is better, and they feel that they get more out of the lecture. Dr. Carroll has tried many innovative teaching methods over the years, and nothing has been so unanimously well received by the students as this lecture process.

One problem with using this lecture method is that in many classrooms, the projector cannot be adjusted to shine on the board. This problem can be overcome if a smart board or electronic tablet is incorporated into the classroom. The figure can be projected on the screen, and the smart board or tablet can be used to mark it up by hand, just as it would be marked up on the chalkboard. The resolution of the smart boards is not as good as a chalkboard, so the handwriting will be harder to read. The tablet resolution is as good, if not better than chalk. Faculty can start the topic on the screen, using the space available, and then finish the topic on the chalkboards or whiteboards in the room.

The resolution and quality of the tablets or tablet PCs make them an excellent substitute for the chalkboard. They can be regarded as “electronic chalk”. The only problem with replacing the chalkboard with the electronic tablet is lack of board space. There is only one screen in the classrooms. It is possible to put approximately two boards of information on one screen using the electronic tablets, but many engineering problems require more than two boards of space, so the information gets crowded on the screen. This becomes especially problematic in distance education, when it is not possible to use the chalkboards in the room. The information technology people will argue that it is possible to switch back and forth between pages on the screen, and that the students already have the information in their notes so they can look at their notes and the new page on the screen. They are wrong. Switching back and forth does not work well in the lecture. The reason that the chalkboard is such a great technological invention for teaching is because it frees us from our short term memory. The teacher can put many ideas on the board at once and reference back and forth between them. Switching back and forth between pages takes away the principal benefit of the chalkboard. In the future we will have multiple screens in the classroom and distance students will have multiple screens on their computers (or perhaps a very large split screen). At that point we will be able to replace the chalkboard with electronic chalk.

Distance Education – Tablet PC Computers

Distance education has become an increasingly common and important part of higher education in the last two decades for two reasons: 1) increased demand for education, and 2) the exponential rate of progress in information and communication technologies (Buachalla, 1989).

According to the National Center for Education Statistics, more than 60% of public and private not-for-profit 2- and 4-year institutions offered distance education courses in 2004-2005. In many educational institutions, distance education has moved from a peripheral position to a “central-stage” position (Buachalla, 1989).

Despite all of the benefits and convenience that distance education offers, the absence of face-to-face contact has created difficulties for distance learners with regard to communication and interaction with their instructors and among their peers (McLean et al., 1998). Student/teacher interaction is a critical constituent of learning, as students are more actively engaged in learning when they interact with instructors (Wang et al., 1992). Research also suggests that interaction in distance courses is associated with higher achievement and student satisfaction (e.g., Zhang and Fulford, 1994).

The issue of student/teacher interaction in distance education courses is especially problematic in engineering since engineering students tend to have learning styles that are active and visual (Felder, 1988; Felder and Brent, 2005). For example, research has suggested that 80% of engineering students are active learners and 75% are visual learners (Fowler et al., 2002). Homework problems constitute an essential component of instruction in most engineering courses since it is through these exercises that course concepts are fully illuminated. These assignments are challenging, and students usually require additional discussions with instructors in order to master the nuances of the subject matter. Instructors can offer context, connections with previously learned concepts, and guided step-by-step instructions pertinent to specific assignments that help students learn the course concepts and develop the ability to develop solutions by themselves (Humar et al., 2005).

Visualization is an important element in explaining engineering concepts and developing problem-solving skills since engineering technical writings rely heavily on equations, special notations, and graphs (Humar et al., 2005). In the typical on-campus course, instructors can provide individualized instruction and assistance to students during office hours in a traditional manner (e.g., using a chalk board or marker board). Students can show the instructors where they are having difficulty, and the instructors can provide the guidance and assistance necessary to help students develop proficiency. Students can observe the logical sequence required to solve engineering problems in a face-to-face meeting with their instructor. Unfortunately, this is often impossible in distance education environments, and the lack of visual interaction is an obstacle that inhibits the efficacy of engineering distance education. For success, distance education must use technological means to facilitate interaction and make interaction more effective (Roblyer and Wiencke, 2003).

When applied properly, information technology can be used in educational settings to support teaching and learning (Leidner and Jarvenpaa, 1995). The advancement of mobile technology has accelerated the use of mobile devices in educational settings (Hoppe et al., 2003). The Tablet PC, as one of the emerging mobile devices, has shown promise and potentials in educational settings. With a touch screen and digital pen, the Tablet PC not only functions as a PC, but also allows the users to draw sketches or take notes on the screen with natural handwriting, which can be revised/edited and saved for future access.

In order to conduct office hours for distance students, homework files were developed, with one homework problem per page. The homework files are similar to the lecture files, but are the homework problems the students are assigned to work. To start the virtual office hours, the instructor creates a session using Webex as a host. Students can join the session by signing in through Webex using their computers at home, at the library, or even at a coffee shop. When a student logs into the session, a bell rings on the Tablet PC to alert the instructor that a student has arrived virtually for office hour help. The content of the Webex session from the instructor's Tablet PC computer will then be displayed on the student's computer. The student can ask questions regarding the assignments using a chat box. The instructor can answer the questions by writing on the touch screen of his Tablet PC using a digital pen (see Figure 3). Control of the screen can be transferred back and forth between the students and the instructor. The handwritten notes can be automatically converted to text messages that appear in the chat box. The instructor can demonstrate to students how to solve problems in their assignments by drawing and writing on the Tablet PC. The instructor can also provide hints to students on solving certain problems by highlighting key words in the problem statement (see Figure 4).

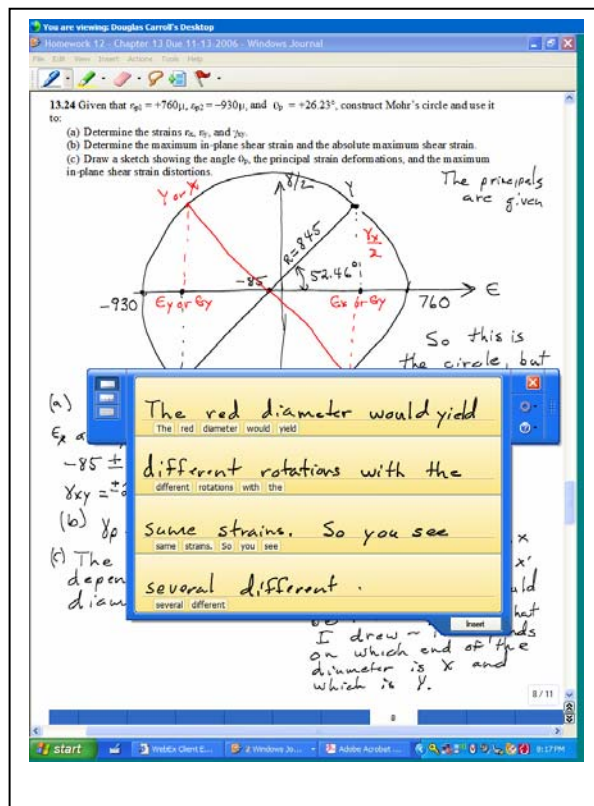


Figure 3: Screen Shot 1

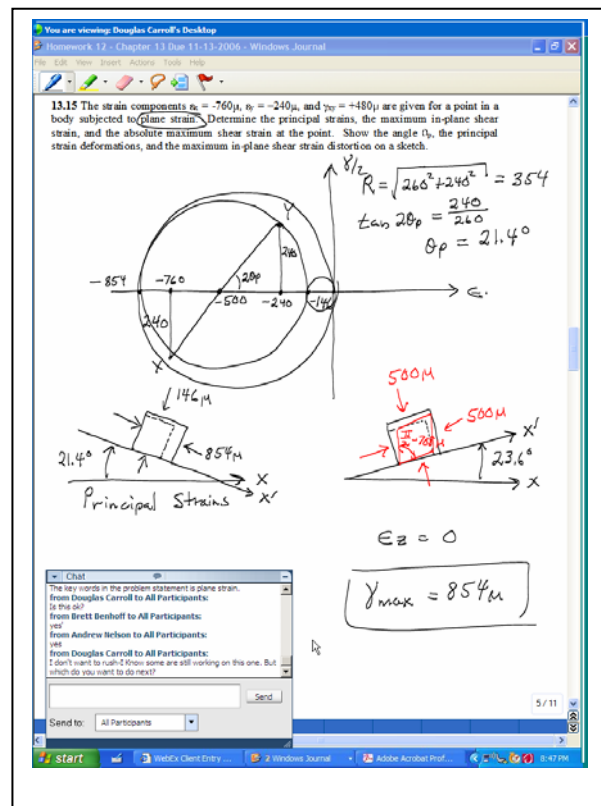


Figure 4: Screen Shot 2

After working one-on-one with a few students doing the virtual office hours, it was decided to try opening the session up to all of the students, including the on-campus students. A two hour block of Webex® office hours was set up each week the evening before a homework assignment was due. It is possible for faculty to conduct the office hours from any location connected to the internet. Students can access the office hours from home, or from any

computer; it is very convenient. The students have taken advantage of this service, with 20 to 30 students logging in and participating each time. The format is that a student will ask a question about a particular homework problem. The faculty member will bring that problem statement and figure up on the screen, and using the tablet feature, will get the students started. He/she then pauses to allow them to work on the problem. If the students need more help, he/she will add further explanation.

In the first semester the distance office hours were offered as part of the class, students regarded them as a curiosity. Many students (approximately half of the students in the class) participated in at least one distance office hour session. In the second semester, as the author has improved in ability to use the technology, it is becoming clear that most students prefer the distance office hours to regular office hours. It is less personal that coming to see the professor in person, but it saves them a trip to campus. It takes less of their time. From a faculty perspective, it is now possible to conduct office hours from home in the evenings, the night before the homework is due, or the night before and exam. A high percentage of students log in and get their homework questions answered in a mass session. It is very effective and efficient use of faculty time. Rolla is a very small and safe community, but there is always some danger for girls getting out on campus late at night. The distance sessions allow the girls to participate fully from the safety of their rooms. The homework sessions have been a very effective use of distance education technology in helping students learn the material in statics and mechanics of materials.

Results

The author has had the unique career experience of working in a service department which specializes in teaching the basic mechanics courses for 18 years. The department offers 8 to 10 sections of statics and 7 or 8 sections of mechanics of materials each semester, taught by a variety of faculty in the department. There is a common final exam for both courses, taken by all students. The final exam is graded consistently so that the same faculty member will grade the same problem(s) for all students taking the final exam. That is, if faculty member A is assigned to grade problem 1 on the final exam, he/she will grade problem 1 for all students, not just the students in his/her sections(s). This unique department and teaching career has allowed for data to be collected to evaluate the effectiveness of the teaching method proposed in the paper.

The first question to be addressed is the student reaction. Do students like this teaching method better than the traditional teaching method? Student evaluations have been conducted every semester, giving an overall rating of the teaching effectiveness of the faculty member on a 4 point scale. Averaging the data over 16 years, a total 47 data points, the author received an average evaluation of 3.47/4. Eight sections have been taught using the new teaching method, and the average student evaluation has increased to 3.68/4 for those 8 sections. Though not huge, this is a significant increase, suggesting that the students like the new teaching method better than the traditional lecture. The maximum possible score is 4.0, so there was not a lot of room for improvement in the student evaluations.

The second question to be addressed quality of the education. Do the students learn the material better with the new teaching method than with a traditional lecture? In this analysis, it

is assumed that the final exam is a good measure of how well the students learned the material in the course. An overall average score on the final is established, as well as the average score in each section of the class. If a section average is above the overall average, then it is presumed that that section of students learned the material better than the average student in the class. Data was generated by taking the average score in sections taught by the author, minus the overall average score on the final exam. During the first 16 years, using the traditional teaching method, sections taught by the author scored an average of 0.16% below average on the final exam. For the most recent sections taught using the new teaching method, all eight sections scored above the average on the final exam. On average they scored 4.16% above the average, which is almost half a letter grade. This shows clearly that the students are learning the material better with the new teaching method.

Summary and Conclusions

It has been possible to use the lecture process described in this paper for several years. Figures could be copied from the text on to transparencies and handouts could be copied for the students. A very organized faculty member could prepare the whole semester of lecture notes in advance and have the bookstore make the copies and sell them to the students in the class. The overhead projector could be used to project the images on the board during the lecture. It is not necessary to have computers and projectors to use this lecture process. The problem has always been that it takes excessive effort on the part of the faculty to prepare the lecture notes and transparencies and make them available for the students.

Technology has become available in the last few years to facilitate the preparation of the lecture notes. Many classrooms now have a projector mounted on the ceiling and a computer system that is reliable and networked. Faculty can walk into the classroom, log in, and bring up the lecture notes just as they would bring them up on the office computer. Textbook companies are making the graphics in the text available so that the faculty member can copy and paste them into a word processor in preparing the notes. It is much faster than scanning or Xeroxing and it generates higher quality results. The four or five pages for a lecture can be prepared very quickly and conveniently. Preparing the files is a quick process; most of the preparation time is spent deciding which figures to use and developing the handwritten notes that are to be put on the board. The files can be emailed to the students, or they can be posted on a university web site such as Blackboard[®]. Students download the files, print them and bring them to class for the lecture.

The distance office hours, conducted using the tablet computer and Webex[®] software has worked out very well for the students. Students are most likely to need help the night before a homework assignment is due. Being able to conduct office hours from home is a real convenience to the faculty member. It also provides the students with the assistance that they need. Far more of the on-campus students utilized the Webex office hours than came by the author's office for regular office hours.

This lecture process has raised the author's personal satisfaction in teaching the statics and mechanics of materials courses. It is possible to spend more time talking with the students during class, and less time writing and drawing on the board. The students are able to spend

more time thinking and less time writing. There is more interaction and more time for questions during the class. A higher percentage of students are able to keep up and follow what is presented. They are able to use their lecture notes when studying. Students are able to work more challenging problems on the exams. Student teaching evaluations have gone up. Written comments received from the students at the end of the semester are very positive about this lecture method. Student performance on the final exam has gone up. Working with the high quality graphics during class makes the lecture more enjoyable for both the faculty and the students. The students learning experience with this lecture process is more beneficial and rewarding than the experience in a traditional classroom.

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