A Remedy for the "Statics" Condition

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Abstract

Historically, Engineering Mechanics/Statics has always been a difficult course for engineering students. The course is central to the entire curriculum in both Civil and Mechanical Engineering. Many courses in the curriculum build on the concepts of Statics. It requires an understanding of the basic principles of Mechanics as well as the ability to visualize objects in two and three dimensions. Central to the course, it requires the student to master the many techniques for problem solving. These techniques require the mastery of vector algebra and a solid background in trigonometry, which is often lacking. Finally, each week of the course builds on the mastery of the work from previous weeks. The student must keep pace with the course – there is no catch-up.

Statics has never been a student favorite at the University. Students prefer to use formulas that they can plug-and-chug. They are resistant to analyzing. Vector cross products has them seeing cross-eyed and dot products has them dumbfounded. As a result, there was a high drop rate in the course. Students attempted to take the course without doing the time-consuming homework required to master the material. This resulted in high failure rate of those that remained in the course.

It was time to rethink the approach to teaching this course with emphasis on student effort. A lecture/recitation format is now used for the day sections. All mechanics classes meet for a multimedia lecture that presents the concepts with vivid graphics and quasi-animation. Then individual sections meet separately for the hands-on application complete with props for the recitation. The key to the success, however, is the cooperation of the students with major use of the internet for communication.

The results have been a marked decrease in the withdrawal rate and those remaining in the course are demonstrating greater understanding of the material.

I. Background

Approximately thirty and forty years ago, the authors were sophomores taking Statics. Before taking this course, students were required to take a four-credit course in Physics that was at least fifty percent Statics. The Statics course was also four credits with a homework load that is double that which is required by today's students. The scope of the material covered was not significantly different than the current curriculum but was non-vectorial with emphasis on free

body diagrams and the understanding of visualizing problems. In earlier years, engineering students were required to take a two-semester engineering graphics course in their freshman year. Descriptive geometry clarified the meanings of parallel, perpendicular, projection, and angles. The hours spent in carefully constructing the graphics exercises in descriptive geometry prepared the student for the meticulous type of work expected of an engineer. It set the tone for learning by doing. It also helped with visualization.

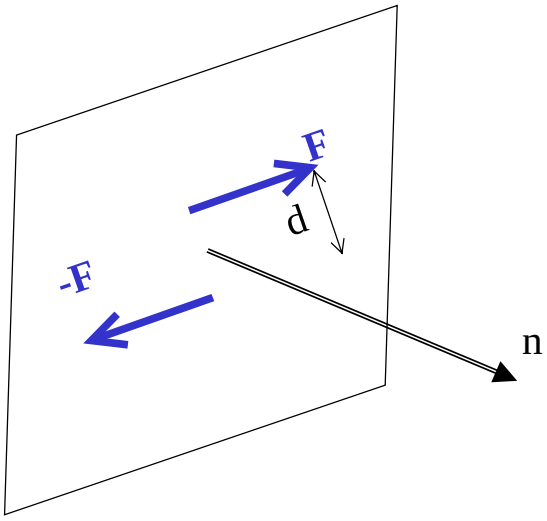
Today's engineering student has a brief experience with engineering graphics with emphasis on computer aided drafting and three-dimensional design software tools. Very little hand drawing is required of today's engineering student. Physics has changed with less application toward the area of Statics. Emphasis on software tools and programmable calculators has eliminated the need for a student to fully understand concepts while cranking out answers by guessing which formula fits the data given in the problem. The art of thinking through a problem seems to have been lost to the technology we impose on them. As a result, there is a high drop rate for the Statics course as students tend to withdraw as soon as they are faced with a challenge. Students attempt to take the course without doing the time consuming homework required to learn the material.

With a new generation of high-tech, video-oriented students, a whole new approach to teaching an age-old topic was necessary. The material is the same, but the presentation has changed.

II. The Approach in the Lecture

All students enrolled in Statics today will attend a class once a week en masse for the lecture portion of the course. The students are encouraged to read ahead in their textbook, then to attend the lecture and primarily listen, taking minimal notes. This is a novel approach - going to class and just listening. Students have been conditioned to take very detailed notes. But how much can they hear or understand if they are busy trying to copy notes from a chalkboard? It is more important for them to absorb the concepts being presented in the lecture portion. Giving their full attention to watching and listening is better than hurriedly trying to take notes and capturing only a fraction of the lecture. This is accomplished by having the diagrams of the material covered in lecture available for download from the course web site. It enables the student to obtain high quality notes without extensive writing. A typical example of the internet diagram and the problem as shown in class follows.

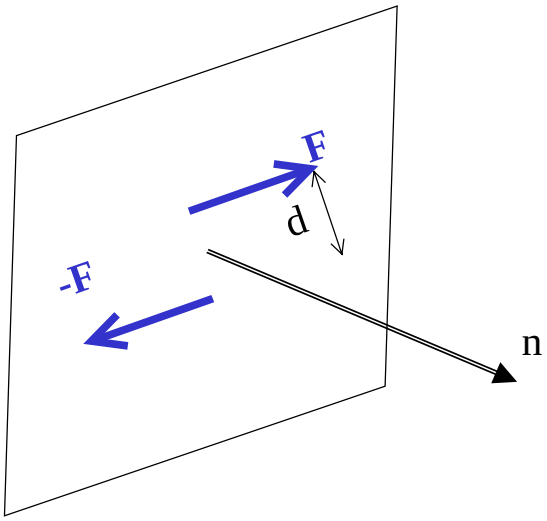
DIAGRAM FROM THE WEB



LECTURE NOTES

The moment lies in the plane of the forces.

One may attribute a direction to the moment by imagining that the moment is rotating about an axis perpendicular (normal) to the plane of the moment.



The change in the presentation of the lecture is also due to the fact that today's students need to be stimulated by visuals. Numerous pictures are used in the lecture portion of the course. These help the students to relate the topics that they are learning to the physical world around them. This is paramount for them to understand applications. Samples of the picture used in the course follow.

The photo illustrates the basic concept of force-the force that acts on the helicopter blades to lift the helicopter and the force in the cable that lifts the package.

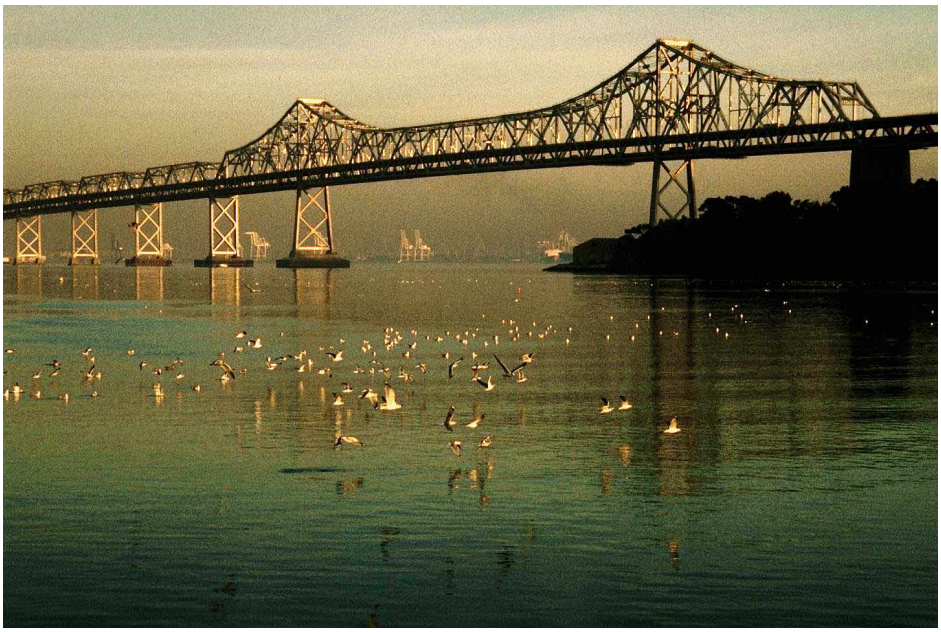
The picture of the cannon illustrates the concept of a particle, the cannonball.

When the canon fires the cannonball acts as a ***particle*** in projectile motion

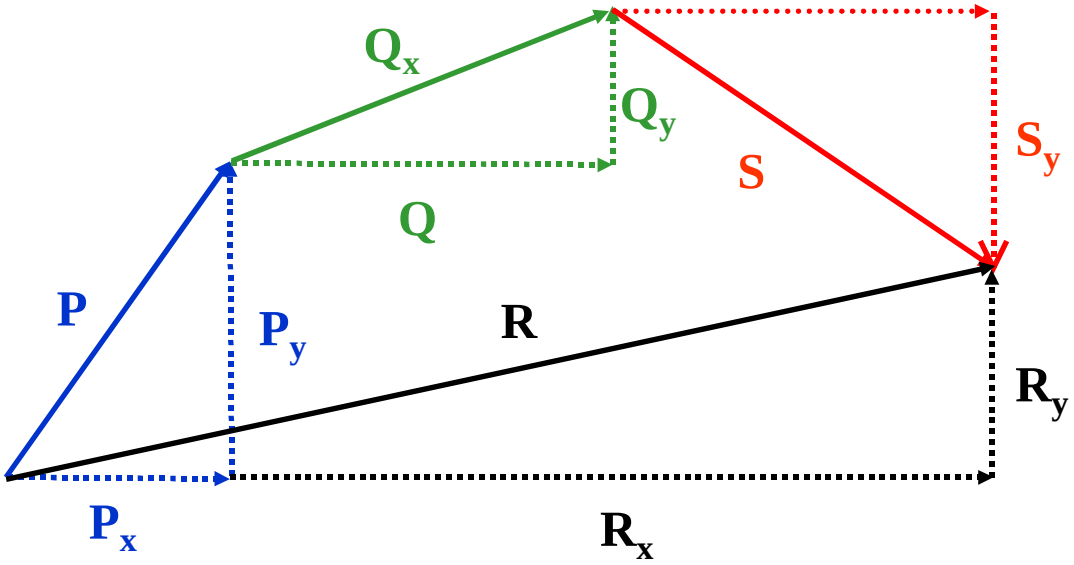
The picture of the train coming into the station gives a sense of inertia and mass.

When you stand next to a large object that is, even moving very slowly, you have a sense of enormous power, ***inertia***

The picture of a truss illustrates the real world use of trusses as well as their beauty.

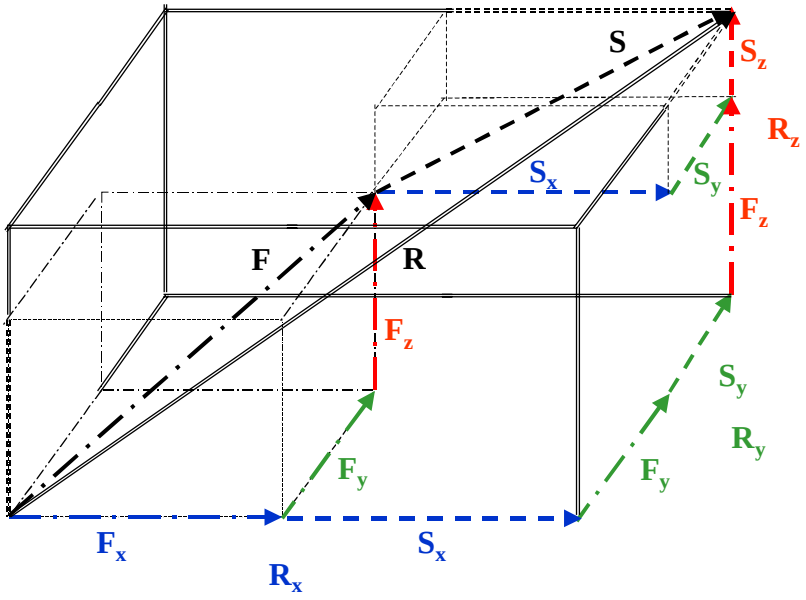


Visuals also include brightly colored graphics to enhance the visualization of vector components of two-dimensional vectors. Normal and tangential vector components that are color coordinated can help the learning experience of determining the resultant of several vectors.

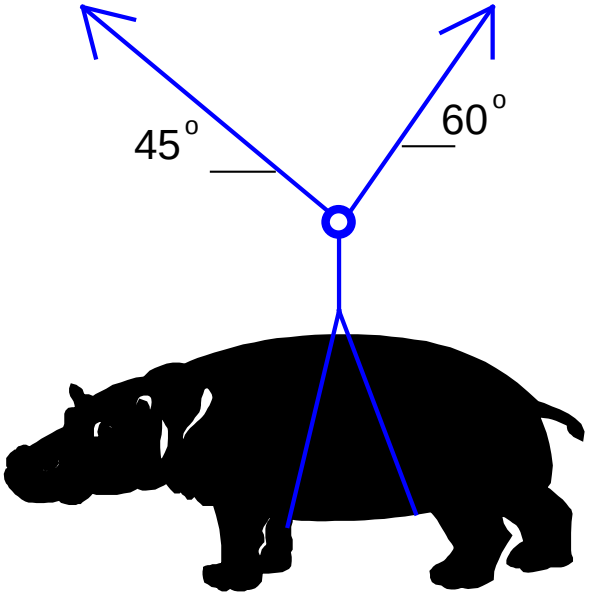


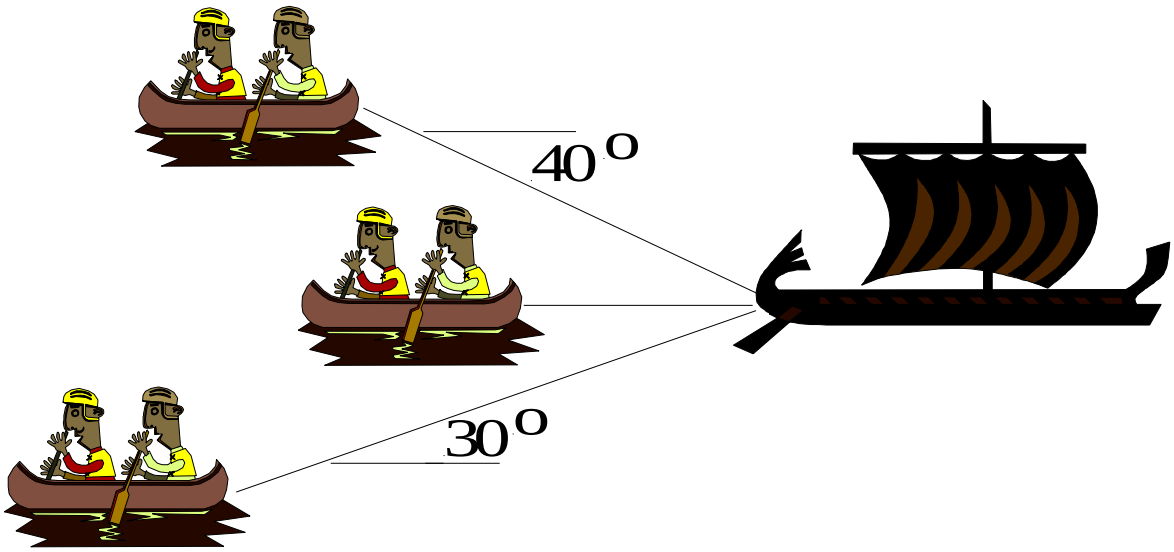
$R_x = P_x + Q_x + S_x \qquad R_y = P_y + Q_y + S_y$

The complex concept of space vectors may be visualized by the use of a color diagram. The colors help to separate the various components of the space diagram and help students to see the orientation of the orthogonal components. This helps them to understand the relationships developed in the formulas. Students are thus encouraged to ignore the formulas and to develop the relations for determining the components based on their visualization of the vector orientation.

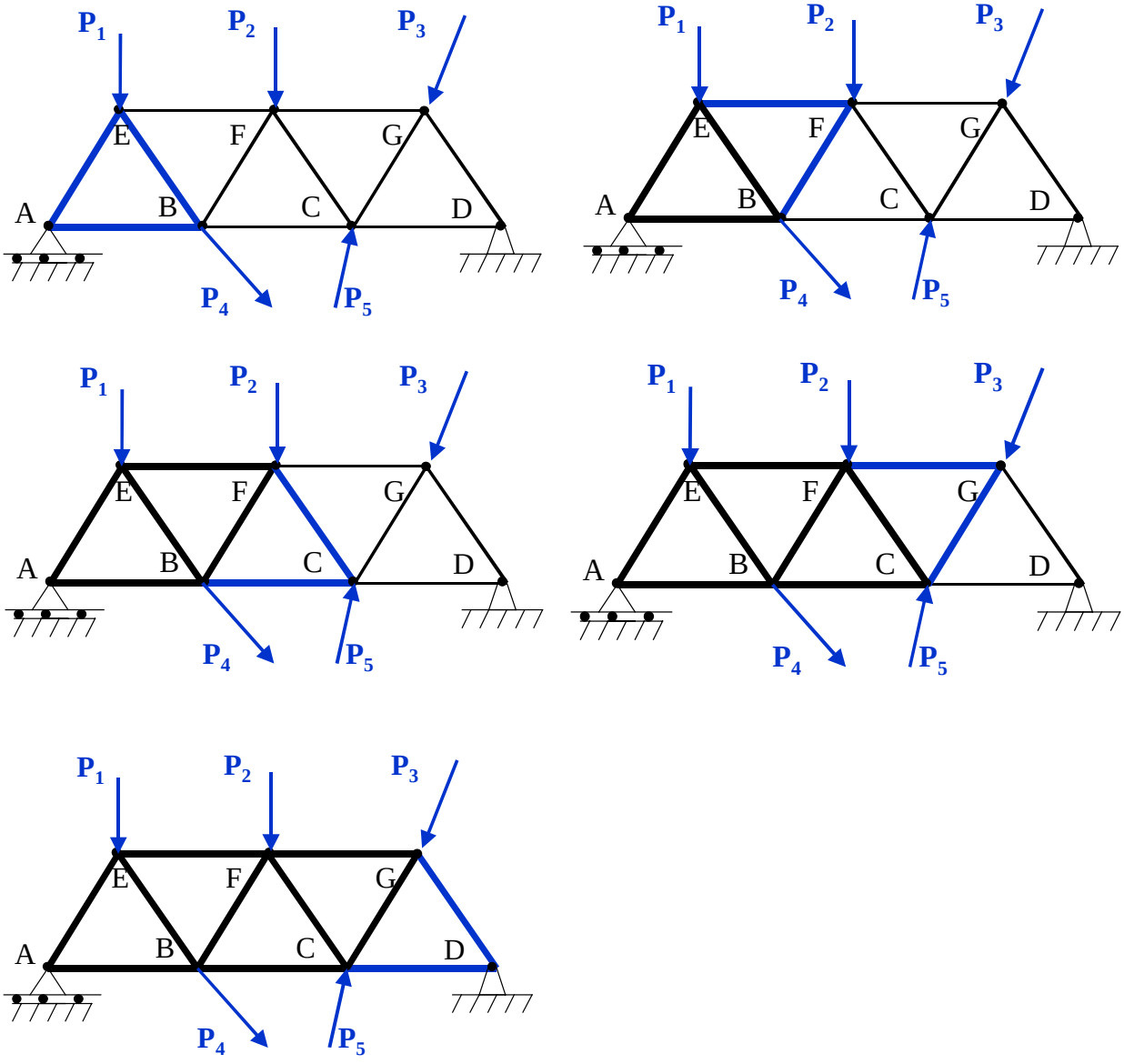


The use of humor in the pictures and graphics also helps to lighten a stressful and complex lecture. This is seen in the examples that follow.





With today's students' appetite for video, motion and entertainment, many of the concepts presented in the lecture are done with quasi-animation using Power Point. A simplified, build for a truss expresses the technique used to hold their interest in what would otherwise be a dry lecture. This is illustrated with the series of slides that follow.



Measuring the Success of the Approach

It is well known that, "all educational experiments are doomed to success". This result is usually attributed to the extra time and effort of the faculty in the experimental period. Undoubtedly, this conclusion is accurate. Several of the authors' colleagues have asked for proof of the success of the course. To do this on a statistical basis would require years of data with sections taught in the traditional mode and in the experimental mode. The direct evidence that is available:

- The students attend class. There is over 90% attendance throughout the semester whereas in the traditional class, the attendance dropped off throughout the semester.

- Student evaluations of the course and the instructor is consistently 3+ out of a possible 4. In the traditional course, the evaluations were usually 2 or less.

II. The Approach in Recitation

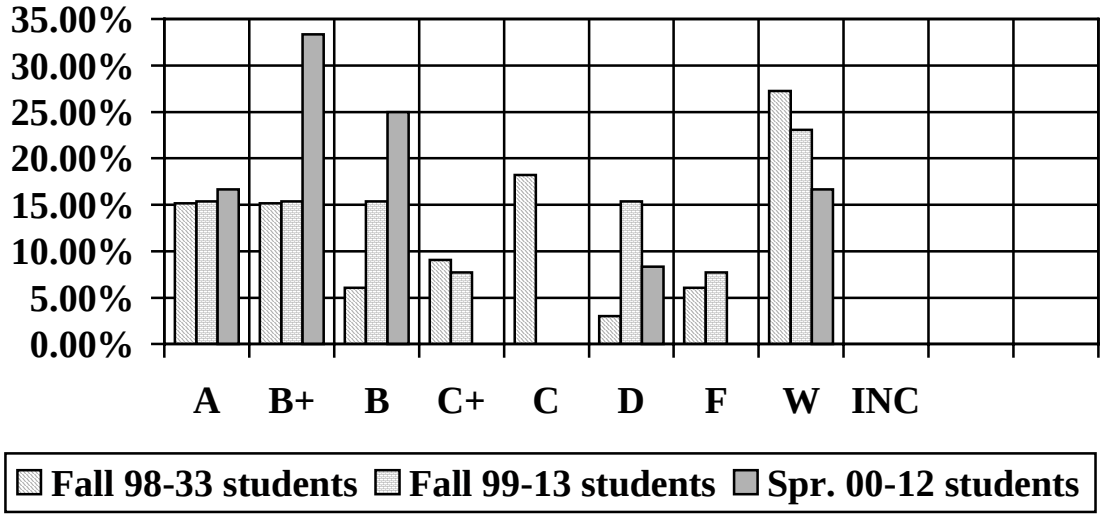
Students separated by different sections meet on another day of the week for the recitation portion of the course. For this portion, the key is the use of the internet. All the recitation examples that will be presented are available on the internet in .PDF form. Nothing fancy, just hand drawn and hand calculated solutions to example problems with the addition of hints and notes. Students are encouraged to download these examples following the lecture and prior to the recitation. They are encouraged to follow the examples and match them to the examples in the textbook. They bring the downloaded copies to the recitation class for review. This allows twice as many examples to be presented with alternate approaches presented on the chalkboard next to the projection screen. The use of a SmartCART is used in the recitation. This is a cart fully equipped with a computer, mouse, speakers, a projection system and VCR. The CART also has internet connection from the classroom. This allows access to the website for the course. This is a sample page of the recitation problems: http://eies.njit.edu/~milano/examples.htm

Homework is assigned from the recitation portion of the class and collected the following week. The same week that the homework is collected, the solutions to those problems are posted on the web. The published syllabus has the assigned problems hyperlinked. So each week another set of solved problems appears on the web. Students will access the solved homework problems and review them before their graded homework is returned. If there are any questions on how the problems were solved, an immediate review can occur referring to the web solutions. To encourage the much-needed practice, homework is 20 percent of their overall grade as an incentive to learn the material by doing the homework. For any homework not submitted, a minus one point will be recorded. Again, an incentive to do the homework.

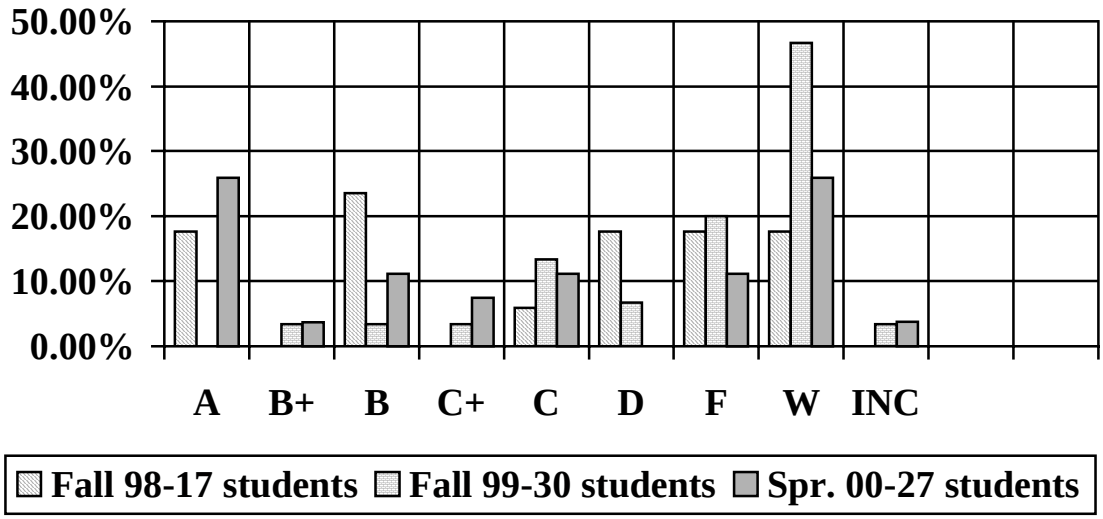
III. Assessment and Feedback

Data has been collected over the past two years during implementation of this approach and compared with statistics of previous years. A withdrawal rate of fifty percent has been improved to about fifteen percent. In prior years, of the remaining 50%, only half of those would pass the course making the passing rate only twenty-five percent. This has improved drastically to about sixty-five percent. The following charts express the changes over the past few years. MECH234 is the Statics course taken by students pursuing electrical or industrial engineering. MECH235 is the Statics course taken by civil and mechanical engineering students. Data was collected for both day and evening sections. The day sections followed the team teaching approach with the lecture/recitation format. But the same instructor taught the evening sections beginning in the spring of 2000. Note the changes in the withdrawal rate and the failing rate. Those students remaining in the course tended to have better overall performance in their final grades as well.

MECH234 - Day Sections



MECH234 - Evening Sections



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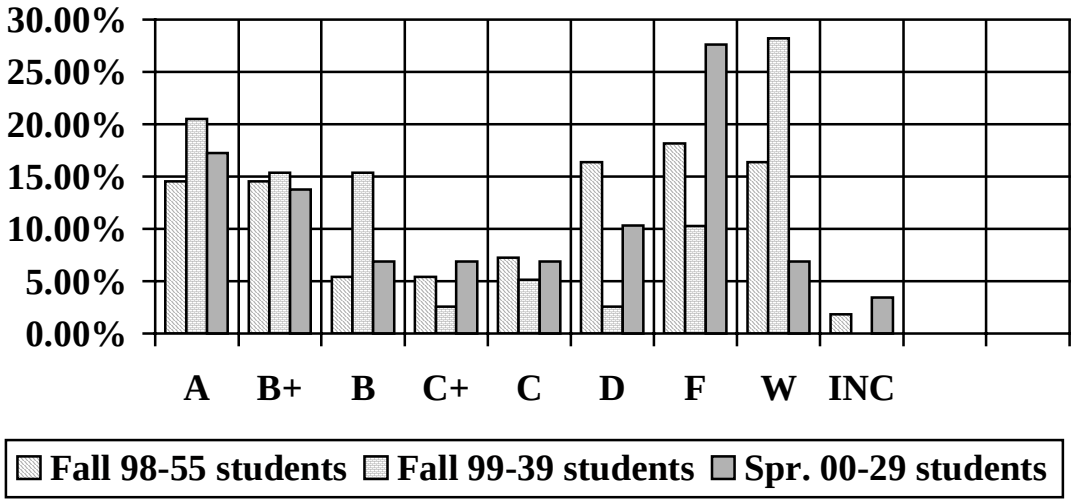
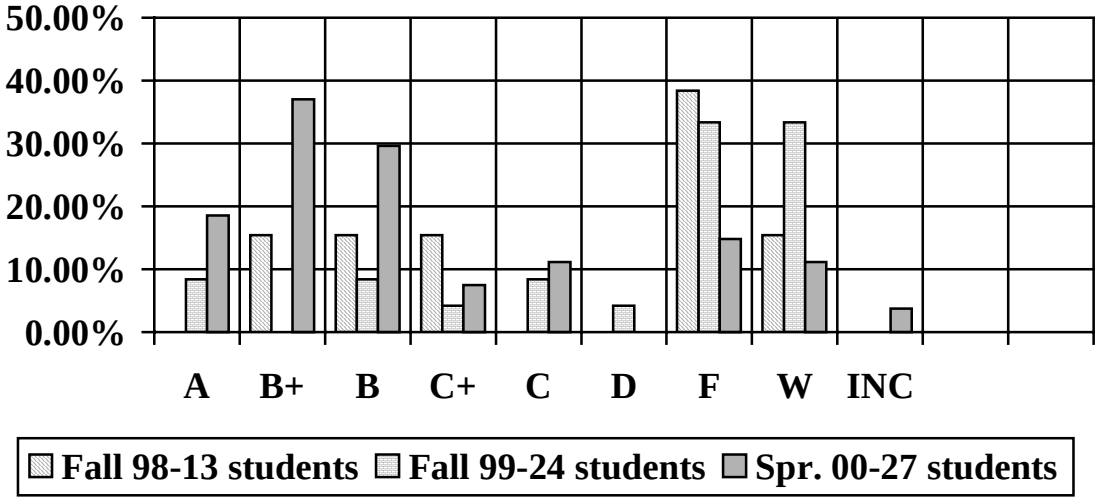
MECH235 - Day Sections

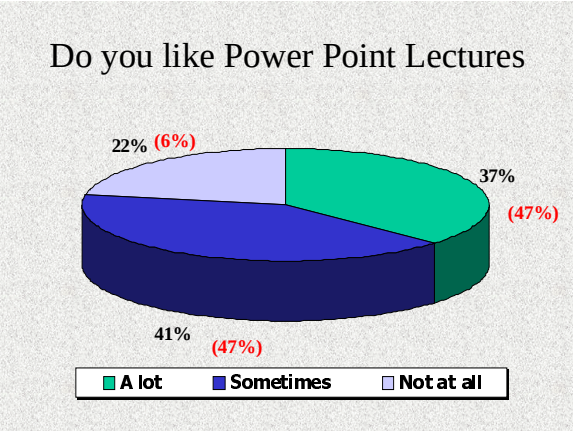


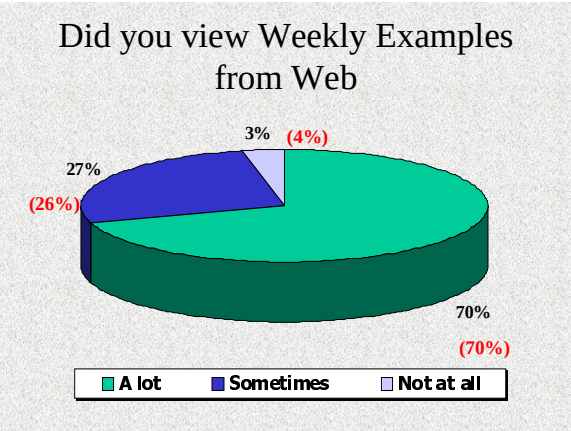
MECH235 - Evening Section

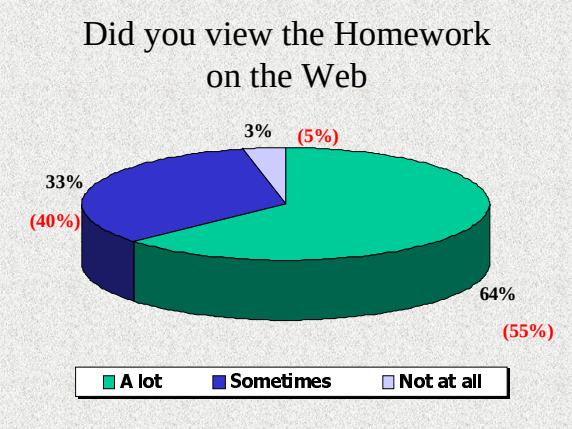


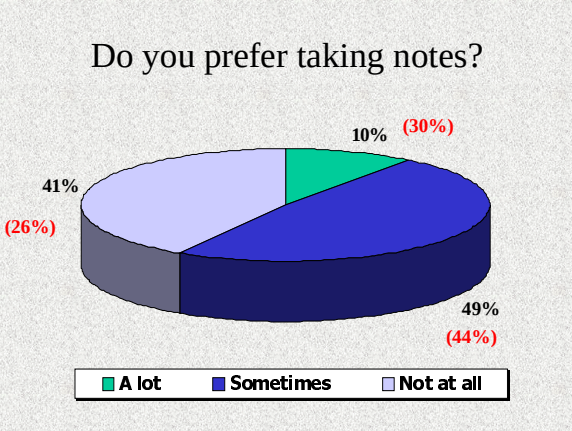
Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition

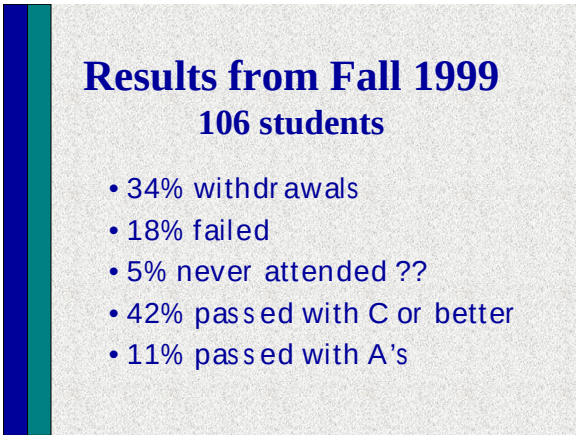
Questionnaires were also used to measure the students' satisfaction with this new approach. Overwhelmingly, the students gave positive feedback with regard to having courseware available on the web. The following charts represent the responses for the 1999-2000 academic year. Data in parentheses (red) are from the Spring 2000 term.

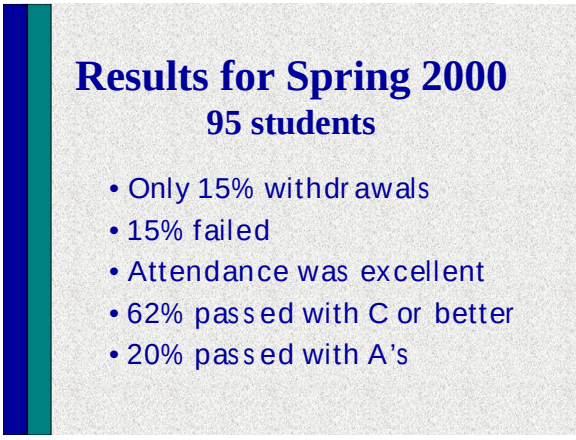












IV Conclusion

The final results of this experiment have yet to be documented since that entails tracking the students through subsequent courses such as dynamics, strength of materials and discipline specific courses such as kinematics, system dynamics and structural analysis. The true test of the effects of this approach will be better known if the students have retained more of the material on vector analysis and can better apply the concept to other application courses. For immediate results, anecdotal comments by students have been similar to these quotes.
"We use a lot of those vectors in the dynamics course I'm taking."
"Oh, gee, I didn't think I'd see distributed loads on beams again, but I have to use that stuff a lot in my strength of materials."
And the one I like best, "Gee, I wish I could take Statics all over again because this time I'd really pay more attention because this stuff shows up again in dynamics and strength of materials."
But, by far the best test of a job well done is when a student sends an e-mail and says "thank you, I learned a lot in your class".

Biography

GERALDINE B. MILANO
Geraldine Milano is currently a Special Lecturer in the Department of Civil & Environmental Engineering at New Jersey Institute of Technology. She received her B.S. in Mechanical Engineering from Newark College of Engineering in 1972 and M.S. in Mechanical Engineering from NJIT in 1978. Industrial experience as an outside plant engineer for NJ Bell Telephone Company and a production engineer, then research engineer for Thomas & Betts Corp. helped her to bring the real world experience into the classroom when she returned to NJIT to teach for the ME Dept. She has also spent several years in administrative rolls as the Director of Engineering Graphics and the Director of Curriculum Innovation during a term in the Dean of Engineering Office.

EUGENE GOLUB
Gene Golub is currently a Professor of Civil & Environmental Engineering at New Jersey Institute of Technology. He received his BCE from The Cooper Union in 1962, an MS in Civil Engineering from Columbia University in 1964 and the PhD in Applied Mechanics from Polytechnic Institute of Brooklyn in 1969.