

# **Lessons Learned from a Newly Developed Hybrid Vector Statics Course Based on Fundamental Concepts and Hands on Experiments**

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## **ABSTRACT**

Engineering education is under considerable pressure to include more and new materials, to restructure the course content using new approaches and technologies and to manage a spectrum of students with diverse backgrounds in spite of the reduced total number of credits for graduation. A group of mechanical engineering faculty have initiated a hybrid Vector Statics course which involves Macromedia presentations, Hands-on experiments, online collection of homework, and Multimedia computer interactive games. The main objective for developing the new hybrid course is to reduce the existing 44% failure rate among approximately 800 students who enroll in this course annually. In this paper the development process of the course is presented and integration of previously developed and tested Concept Inventory (CI) test as an assessment tool for course is discussed.

## **Introduction**

Engineering education is under considerable pressure to include more and new materials, to restructure the course content using new approaches and technologies and to manage a spectrum of students with diverse backgrounds in spite of the reduced total number of credits for graduation. Most engineering curricula have become more intensive and thus students are required to spend more time for each subject. California State Polytechnic University in Pomona, California has one of the largest engineering programs in the US with over 4,500 undergraduate students. On the other hand, more than 84 percent of students at CPP are working during the week [1]. In recent years, student attrition has been a problem for many engineering programs across the nation such that a significant number of students drop out in their first- and second-year. As indicated in the EERP report on student attrition [2], the primary non-university related reasons students claimed for leaving their studies were the difficulties managing work and class schedules, and commuting to campus.

Vector Statics is the first hardcore engineering class, as required by almost all the majors at the beginning of sophomore year in the College of Engineering at Cal Poly, Pomona. During the academic year of 2004-2005, 27 sections of Vector Statics and 8 sections of Vector Statics Laboratory were offered for approximately 800 students. Vector Statics has been a bottleneck course due to its significant number of failures and repeats by students enrolled in it. In a survey with 319 students who took the course from various majors during fall 2001 and winter 2002

quarters, over 44% of them did not have the passing grades, and that was a small increase from 40% taken from the survey during the academic year 2000-2001 with 517 students. The high repeat and failure rates of this course significantly hamper the students to move up to their engineering curricula, resulting in a high attrition rate of the engineering students.

### **The problems addressed by the hybrid course**

The ME department has addressed the failure problem in many different ways. One way was to provide an additional one-unit Vector Statics Mechanics Laboratory, which was developed based on the study on cooperative learning in engineering through academic excellence workshop [3]. Under the cooperative learning environment, the students demonstrated significantly better performance in learning Vector Statics as noted in their final grade of 2.88 as compared with 1.33 for those who only took Vector Dynamics [4]. In the laboratory, the students learn fundamental concepts of Vector Statics through teacher demonstrations, group projects & discussion, and additional exercises. However, it is a co-requisite to the Vector Statics course only for ME majors, while other majors are encouraged to take it optionally. Subsequently, ME majors tend to have lower rates of failure and repeat in the course (32% vs. 52% from the former survey during fall 2001 and winter 2002 quarters). This also indicates the effectiveness of the supplemental group activities involving students' participation in better understanding of the subject matter.

In an effort to reduce the number of failures and repeats for higher retention and reduced time for graduation of our students we created a 3-unit hybrid Vector Statics course, combining Vector Statics and Vector Statics Laboratory with substantially revised course contents. The large annual enrollment of over 800 students for Vector Statics and additional 250 students for Vector Statics Laboratory also makes it a good candidate for being offered in hybrid format. This new hybrid vector statics course will suffice the course and its laboratory course requirement for ME students without compromising the depth of understanding so that one extra credit can be used for other courses. Students with other majors will get extra learning opportunities through online lab session and online discussion, expecting for better grade and lower failures.

### **The goals and objectives achieved by the department**

In the traditional engineering courses, the most common pedagogy is a face-to-face, teacher-centered "lecture-test" format using textbooks. Despite the non-engineering nature of common online/hybrid courses and paucity of good models of online/hybrid engineering courses, we made a challenging attempt by devoting our major efforts specifically to:

1. Selecting two to three Vector Statics lecture topics and turn them into online interactive learning objects for active learners so that the instructor can deal with major topics of the class with more extended lecture time. The interactive learning objects will include Flash media animations for visual reasoning of each topic, computational tools for engineering design analysis and simulation of problems for online homework assignment and online laboratory discussion. For example, to learn vectors, an important concept in Statics, instead of the usual definitions and math, students are given an interactive Battleship game to practice with vectors. And, students are asked to determine the route from one ship on the map to the next ship using vector notation.

2. Developing a set of remote experiments so that the students can perform online experiments at their own convenience, without having the trouble of long lab hours and commuting to campus. One example includes a truss model with sensors attached to the critical members. Students will be able to alter the applied loads on the truss and monitor the mechanical responses through the Internet.

3. Developing corresponding virtual experiment where the students can simulate the actual experiments using a web browser. For the virtual truss experiment, the students can apply loads on a truss model, evaluate mechanical responses on selected critical elements, and compare the results between the virtual and the remote experiments.

4. Use of the problem bank for assignments and quizzes.

It should be noted that all of the interactive learning objects have been woven into weekly learning modules. Each weekly learning module will also contain timed end-of-topic and end-of-week tests for progress monitoring and grading.

Specific deliverables shall include the following;

1. Interactive Learning Objects: The proposed Interactive Learning Objects (ILO) is short-bite size lessons that are developed in a short period of time (ex. 10-15 minutes). Each object will include meaningful graphics, animation, audio and/or video to illustrate a particular concept. These ILOs can be used as part of a course or can be used as a stand alone supplement. Each learning object will address a particular learning concept and one will build on the other. These objects will be developed using sound instructional design principles by organizing the Statics course into manageable and logical chunks of content.

2. Computer Software for Virtual Experiments: The Equilibrium Toolbox (EQT) has been developed using the numerical analysis software, MATLAB, by taking advantage of its user-friendly interactive graphic user interface and multiple document interface capabilities. The EQT has a collection of vector and Statics analysis packages for fully interactive CBI of Statics lecture and lab sections so as to alleviate the burden of many trivial and time-consuming activities such as performing repetitive calculations, back solving equations, but also to solve complex open-ended computer assignment problems and term projects for improved understanding on vector Statics [5]. The EQT has been used in the classroom setting since 2006 winter quarter. It is expected that the software tool should help students to gain deeper understanding on how a mechanical system works and thus to develop improved engineering intuition for following mechanics courses such as strength of materials, and design of machine elements. Since it requires MATLAB software to use the EQT toolbox, it is necessary to adapt a number of analysis packages in the toolbox to be run by using the MATLAB Web Server so as for the student to use it at home using the Internet.

3. Teleoperated Virtual Experiments: Two sets of teleoperated remote experiments will be constructed. One will be a force and moment equilibrium test setup so that the students can learn vectorial natures of the force and moment and subsequent equilibrium conditions. The other is a reconfigurable truss model constructed with metal members and strain gauges attached to the critical members for online monitoring of the resulting stresses over the Internet. With this setup

the students can conduct a design project using the above computational tool and the experimental truss model. For example, the student constructs a bridge model and conducts computer simulations for optimum configuration. And then the actual truss model is constructed in the lab and tested under the physical loading conditions. One target goal would be to develop a bridge that ought to carry a specified load but with a cost below a target value or number of members.

This shift of paradigm in teaching traditional engineering courses will bring precipitating changes in offering other traditional engineering courses in online/hybrid format. Our efforts will continue to offering other bottleneck courses in hybrid format such as Vector Dynamics, Strength of Materials, etc. Those courses also have shown similar or even higher failure and repeat rates in the department survey.

### **Description of the course**

The course was developed by defining the course modules, the learning units within each of the course modules, and then the learning activities within each of the learning units. Detailing the process in this way helped development of the course in a number of ways such as:

1. being certain that our student assessment for that learning unit can reflect what our team taught and what we want them to know upon completion.
2. being able to completely map out before we even start thinking about which models/learning units we will make interactive.
3. Identifying the types of interactions/learning experiences we want the students to have will and how we will gather or produce those materials.

### **LEARNING MODULE PLAN**

Learning Module plan consisted of an overview of the course projection plan which contained:

- a) **course goals**, a broad statements indicating what the students will learn from the course.
- b) **course objectives**, descriptions of measurable outcomes that students should be able to demonstrate upon completion of the course
- c) **course rationale**, brief justification of why the students need to learn this course material. and
- d) **module outline**, description of how the course content will be grouped.

### **LEARNING UNIT PLAN**

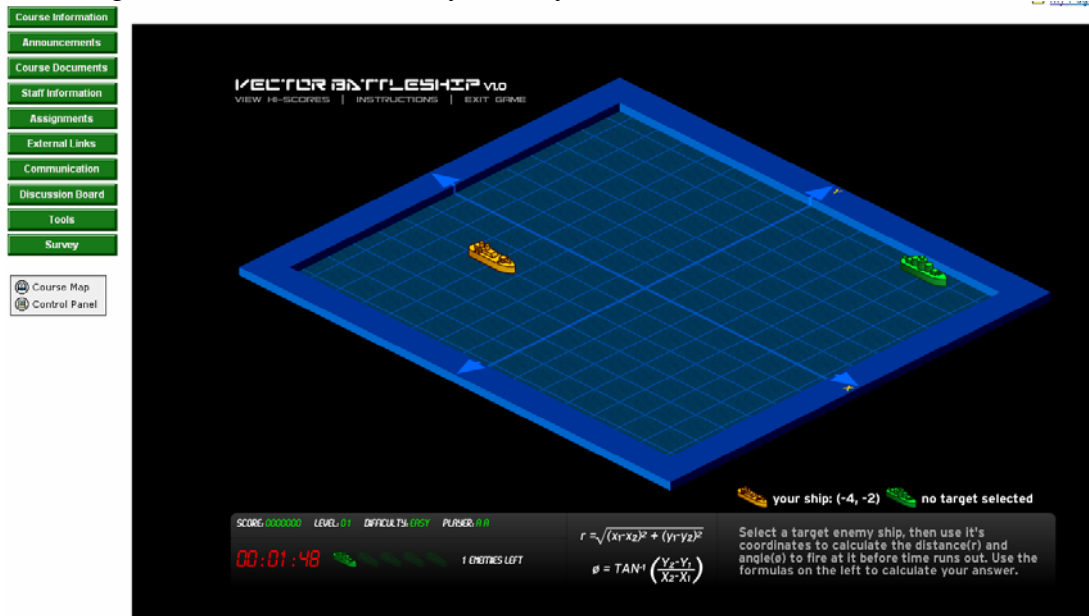
Learning unit plan is a component of the Learning Module Plan which consist of:

- a) **module name**, module under which the learning unit is grouped, if applicable.
- b) **learning unit name/topic**, broad statements indicating what the students will learn from the learning unit.
- c) **learning objective(s)**, descriptions of measurable outcomes that students should be able to demonstrate upon completion of the learning unit.
- d) **rationale**, brief justification of why the students need to learn the topic.
- e) **learning unit content**, what is to be taught.
- f) **instructional procedures**, how you will help the students connect with the content.
- g) **evaluation procedures**, how you will measure outcomes to determine if the material has been learned. The evaluation should be based on the **LEARNING OBJECTIVES**

- h) **materials and aids** , what is needed in order to teach this learning activity. This includes borrowed, created, or adapted course content and other resources such as video, audio, graphics, applets, presentations, external websites, digitized handouts, etc.

### Interactive Learning Game developed for the course

The Battleship game has been developed for Module 0 for students to practice with vectors. The way the game works is that the student starts the game in the Blackboard course developed for the course and the student calculates the position vector of another ship that he/she wants to fire at. The game has been successfully used by the students to learn about the vectors.



### Online Homework and Grading System

PH GradeAssist is an online homework program that comes preloaded with questions developed for the textbook adopted for the hybrid course. Students can complete class assignments, practice skills, and take tests using PH GradeAssist. An example of a sample homework problem is shown below.

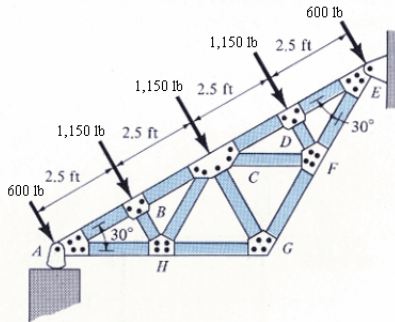


Question Bank: Chapter 6  
Description: 6.184

Jump To: [Question](#) | [Information Fields](#) | [Solution](#) | [Annotations](#)

**QUESTION:**

The Fink truss supports the wind loads shown. Determine the force in each member and indicate if the members are in tension or compression. Approximate each joint as a pin. Enter all force values as positive numbers. Use the results of your calculation to determine if the unknown force is in tension (a positive number) or in compression (a negative number).

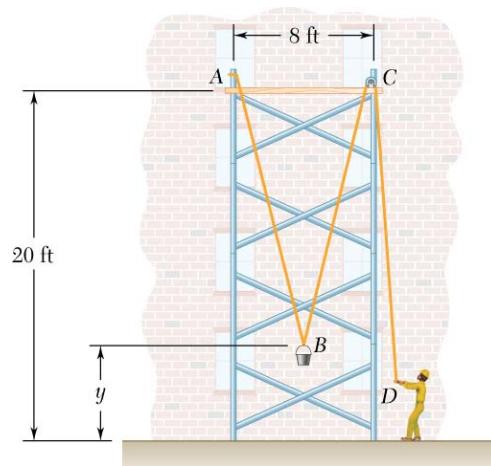


BH	<input type="text"/>	lb	compression
CH	<input type="text"/>	lb	(Click for List)
GH	<input type="text"/>	lb	tension
CG	<input type="text"/>	lb	(Click for List)
FG	<input type="text"/>	lb	(Click for List)
AH	<input type="text"/>	lb	(Click for List)
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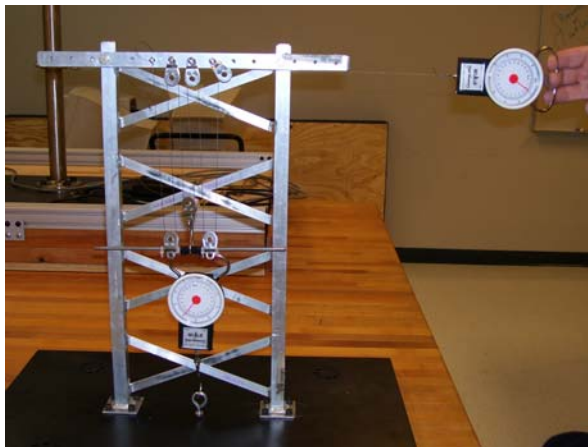
### Hands on Experiments

Efforts have been initiated to construct three sets of hands-on vector Statics experiments. One of these apparatus is a simple pulley-and-rope system. In this system 2-D vector resolution and decomposition and force equilibrium of a particle is under investigation. A painter is raising a heavy paint bucket and the pulley system will help the painter to raise the bucket. For the student, this is a typical homework problem which will result in an answer indicating the correct answer for the tension required by the painter in order to raise the bucket. For the instructor, it is another example of Free-Body-Diagram (FBD) applied to a pulley system. There are many aspects of this problem that is not completely revealed to the students, these are the ones that will be an eye opener for the students especially for the average student who lacks ability to connect mathematics with the application of the problem. By building a model of the problem which is shown in Figure 6 and 7, not only the answer to the given problem is revealed but also different experiments can be performed during the lecture in order to demonstrate the effectiveness of the pulley system. For instance, as shown in Figure 6 which is one of the many configurations of this experiment, students can see that by applying a 5 lb force on one end of the pulley, there will be 30 lb force developed by the cables and the pulley system. By drawing the FBD of the system, the existence of 30 lb force at the other end of the pulley system is proved. In Figure 6, it is demonstrated to students that the reason the scale is reading less than 30 lbs is because the horizontal component of the cable in the last pulley is being wasted and does not help raising the bucket. Several other experiments are performed using this apparatus during the lecture in order to engage students into the topic, specially those that have difficulty connecting mathematics

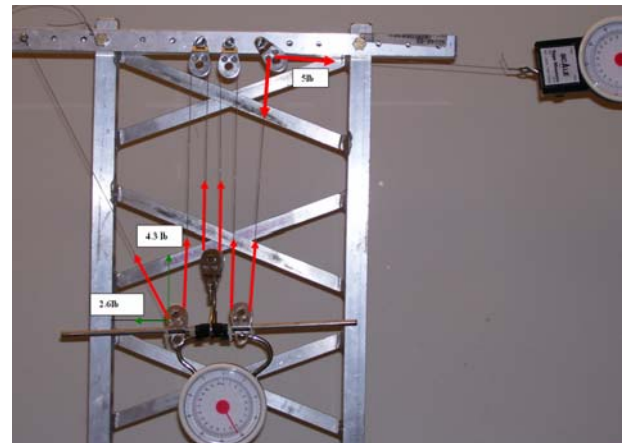
involved in understanding the reason for using pulleys and cables in order to be able to raise a load.



**Figure 1.** Textbook problem 2.C2 (Beer & Johnston 200X) .



**Figure 1a.** Model of the Paint Bucket problem



**Figure 1b.** Component demonstration

### Assessment

The commonly employed rubrics such as homework, quizzes, and exams that we use in our Vector Statics course serve as good indicators of students' understanding about the subject matter we teach and students are tested on; however, these assessment tools may not reflect our student's knowledge accurately in this course. For instance, Vector Statics is a prerequisites course for advanced required courses in engineering, and students must earn a C- grade (or better) in order to take the subsequent courses. However, having a C- in this course means that students are leaving this prerequisite course with ability to solve given exercises, but often they do not have the ability to answer a simple quantitatively question about the fundamental concept in this course. We believe that by implementing an affective assessment instrument that has proved to be successful and effective in measuring the ability of students in Vector Statics will measure the effectiveness of the proposed hybrid course. Two lines of assessment will be made.

Concept inventories (CI): They have recently emerged as tools for assessing students' understanding of the basic concepts in engineering education. By undergoing a rigorous process of validation, engineering concept inventories can provide meaningful primary assessment throughout a curriculum or an specific course such as Vector Statics. The effectiveness of this course is measuring by:

1. Integrating previously developed and tested Concept Inventory test specifically for Statics throughout the course into weekly modules.
2. Making the tests available to the students online via Blackboard and having students to complete the end-of-weekly-module test after each module has been completed.
3. Collecting the student score data from each test scores for each concept and using them to improve the course.

Statistical assessment of Student qualifications and Performances: Additional statistical comparisons will be made to assess the efficiency of the hybrid course vs. regular vector Statics courses.

1. Sample Group: The students are divided into four groups based on the number of completion of weekly modules; full participants vs. partial participants vs. students in a regular section without lab vs. students in a regular section with lab. Due to the prospective randomized nature of this statistical assessment, the sample population is carefully assessed based on their demographic information including cumulative GPA to date, SAT Math scores, prerequisites course grade, number of repetition if any, total number of credits to date, etc.
2. Teaching Method: The same instructor shall teach two sections in the same quarter, one hybrid and one regular.
3. Performance Index and Evaluation: The primary performance index will be the ME214 course grade and the final exam score. Their mean values will be used for statistical comparison using the independent Student t-test. As important as the class performance is the retention of the students and their subsequent academic performance. The students' record will be tracked down for a year to assess their retention and academic performance in general and in specific subjects such as ME215 Vector Dynamics, ME218 Strength of Materials, and so on.

## Conclusion

An online hybrid course has been developed and implemented for Vector Statics course. The method of developing the course has been explained and assessment methods have been successfully implemented. The method of delivery and presentations will be presented in the conference session and assessment data based on the delivery of the course has been obtained. In summary, these results indicate the following:

- Use of Blackboard (Bb) in delivering the course material to class is an **extremely effective** tool.
- Having available PowerPoint presentation of each lecture topic to students outside of class explaining the fundamental concepts is **extremely effective**. As seen from the student comments and mainly performance, 95% of students who took the survey liked reviewing the course lectures after they have attended the lecture and it helped them understand the material better. Also, too much use of power point presentation during the lecture is **not very effective** tool. Students prefer and understand more when example problems are done



on the board; however, they do like a flash of what is available for them online outside of class.

- Use of the online delivery of homework is **NOT very effective** tool. Many students feel that they prefer traditional homework over the online homework. However, if the online homework is implemented such that everything such as internet connection, printing issues, logging issues, and finally the grading issue is resolved and in smooth operation, it can replace the traditional way of assigning homework successfully.
- In a survey question 43% of students stated that they won't attempt to do the homework if homework is not graded for credit. The authors interpretation of this percentage is that if we do not collect homework to give credit for it we basically loose 43% of our students in the next lecture they have on the topic because they have not attempted the homework to understand the material we discussed in the previous lecture. If we also add to this percentage possibility of failure of the delivery of the material to students from lecturer side what we face is that more than 43% have no clue of what was said in the last lecture. This all means that if we do not collect homework for credit our failure rate in the class should be at least 43% plus additional percent for different reasons.
- Last, but not the least, **Online system of delivery** is **effective** to deliver supplementary material such as preparation for a midterm, a final exam or practice exams for different topics.

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