

## **2006-2091: USING COMPUTER ANIMATIONS IN TEACHING STATICS CONCEPTS**

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# Using Computer Animations in Teaching Statics Concepts

## Abstract

In many institutions, Statics is one of the first purely technical courses that most engineering and engineering technology students encounter. This places a considerable burden on the course instructor to present engineering concepts in a way that will not only enhance learning, but also attract and retain the interest of students who are looking into pursuing engineering related careers. If not well presented, the Statics course can be an intimidating experience that discourages learning. This intellectually demanding course is frequently taught in a lecture format that makes it difficult for students to make the connection between the theoretical concepts and the corresponding physical phenomena. This paper describes a Statics course that uses a combination of animations and simulations as well as physical models to teach basic concepts. The course takes advantage of the multimedia capability of the computer to help illustrate the theoretical principles that underlie the observable physical phenomena. In particular, the computer's animation capabilities proved to be of great value as they allow the instructor to present procedural steps in problem solving in a succinct yet fully engaging manner. By sequentially presenting the steps involved in the process, it was possible to demonstrate the analytical procedure much more effectively than any textbook can. This proved to be a highly popular learning tool for the students.

## Learning Styles

Statics is one of the first purely technical courses in the academic careers of most engineering and engineering technology students. This makes Statics a make or break experience for students aspiring to engineering careers and places a considerable burden on the instructor to teach in a way that will not only enhance learning, but also attract and retain the interest of students. Tobias has shown that introductory science courses are responsible for driving off many students who have the initial intention and the ability to study scientific fields but instead switch to nonscientific fields<sup>1</sup>. The reasons she gives include (1) failure to motivate interest in science by establishing its relevance to the students' lives and personal interests; (2) relegation of students to almost complete passivity in the classroom; (3) emphasis on competition for grades rather than cooperative learning; and (4) focus on algorithmic problem-solving as opposed to conceptual understanding.

Recent educational research shows that students' approach to learning is characterized by different learning styles<sup>2,3</sup>. Instructors will also have their own corresponding teaching styles. Students whose learning styles are compatible with the instructor's teaching style tend to retain information longer, apply it more effectively, and have more positive post-course attitudes toward the subject. Students often drop out of science and engineering courses because of failure to address their learning styles. To help instructors understand their own teaching styles as well as the learning styles of their students, various learning style models have been developed. Four of the most well-known learning style models are: Myers-Briggs Type Indicator (MBTI), Kolb's

Learning Style Model (KLSM), Herrman Brain Dominance Instrument (HBDI), and Felder-Silverman Learning Style Model (FSLSM). The Felder-Silverman model is particularly suited to engineering education and is the basis for the work described in this paper. The FSLSM model classifies students according to the following categories:

- *sensing learners* (concrete, practical, oriented toward facts and procedures) vs. *intuitive learners* (conceptual, innovative, oriented toward theories and meanings);
- *visual learners* (prefer visual representations of presented material--pictures, diagrams, flow charts) vs. *verbal learners* (prefer written and spoken explanations);
- *inductive learners* (prefer presentations that proceed from the specific to the general) vs. *deductive learners* (prefer presentations that go from the general to the specific);
- *active learners* (learn by trying things out, working with others) vs. *reflective learners* (learn by thinking things through, working alone);
- *sequential learners* (linear, orderly, learn in small incremental steps) vs. *global learners* (holistic, systems thinkers, learn in large leaps).

Traditional engineering instruction is biased in favor of intuitive, verbal, deductive, reflective, and sequential learners. To improve overall student learning and to expand the student pool, it is important to develop educational materials that address the needs of students outside of these favored categories. Zywno has shown that the use of multimedia designed to address the needs of students not favored by the traditional approach can significantly reduce their performance disadvantage<sup>4</sup>. The work described here is an attempt to reach out to these students.

### **Design of Instructional Materials**

Most students and instructors are used to the traditional lecture format, with the instructor serving as a 'talking head' and using the blackboard or whiteboard to explain concepts and demonstrate problem solution procedures. The advent of new classroom technologies however has allowed this pedagogical approach to be expanded in significant ways that benefit the learning process from both the instructor's and the student's perspective. Use of these new technologies can enable the student to learn more effectively by using learning materials that are designed to capture and retain the attention of the students and actively engage them in the learning process. Experience with distance education indicates that a successful course should incorporate multimedia presentations including a mix of the following characteristics<sup>5</sup>:

- Active involvement by the students
- Multiple presentation media with planned change elements to hold student interest
- Planned silences to allow students to think
- Animations and simulations where appropriate
- Actual physical models of reasonable size if possible
- Examples of practical applications

These concepts can be equally applied in a regular classroom. For the course described in this paper, Microsoft PowerPoint® was used heavily to provide the enhanced learning environment described above and to address the needs of sensing and visual learners in particular. PowerPoint allows the instructor to plan out the main points of the presentation so that less time is spent in

writing and more on explanation. In particular, PowerPoint's animation capabilities proved to be of great value as they allowed the instructor to present procedural steps in problem solving in a succinct yet fully engaging manner. For example, consider the basic process of finding the resultant of a vector using the Parallelogram Law. This is a simple process that is well described in standard textbooks and by instructors in the traditional classroom. But PowerPoint's animation capabilities can be utilized to present even this concept in a much more engaging way. The students can watch the gradual build up of the various steps in the problem solution in a computer animation. By presenting the individual steps in the process sequentially, it is possible to simulate the action of vector addition much more effectively than any textbook can. Figure 1 shows a series of PowerPoint frames in such an animation.

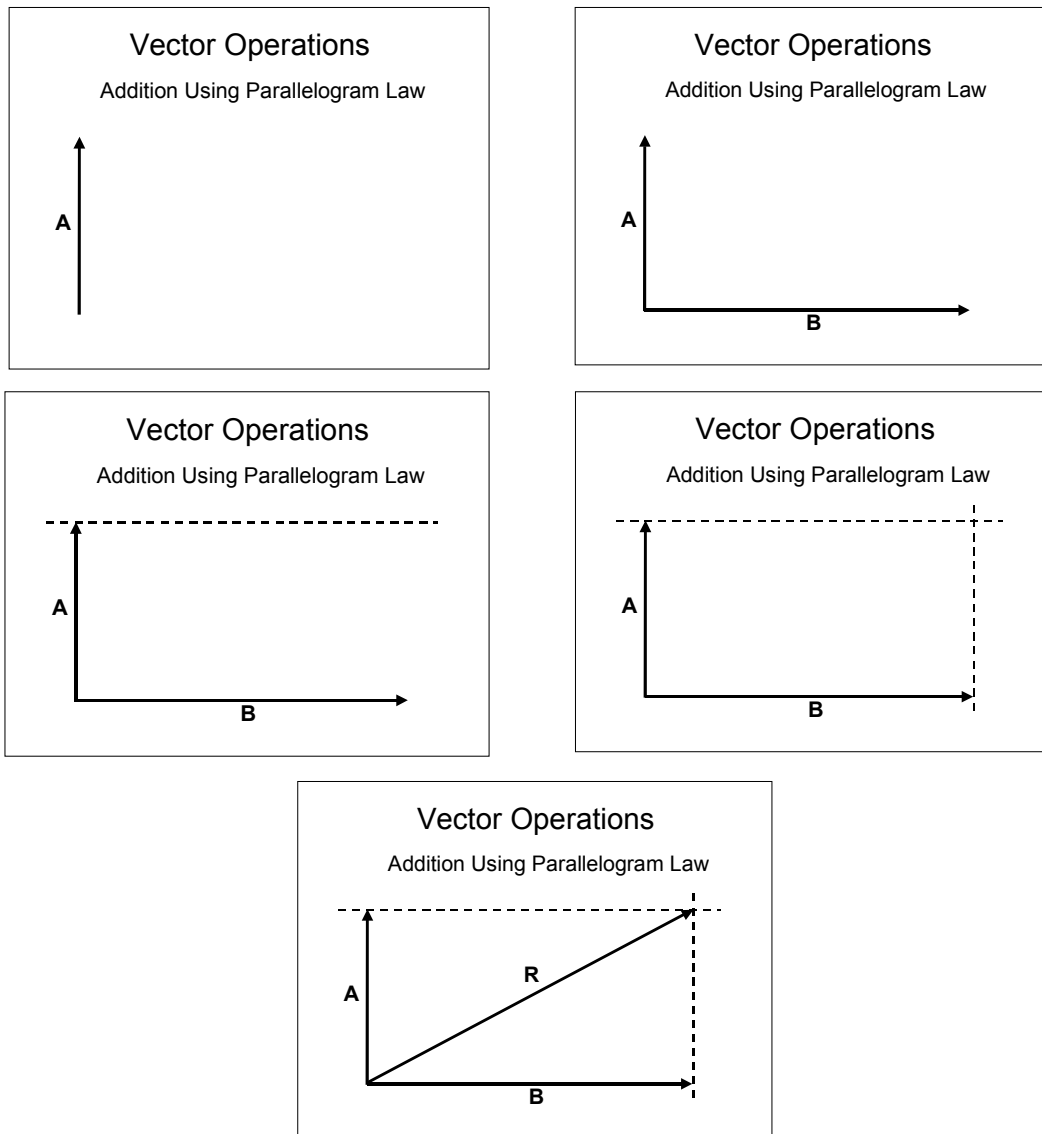
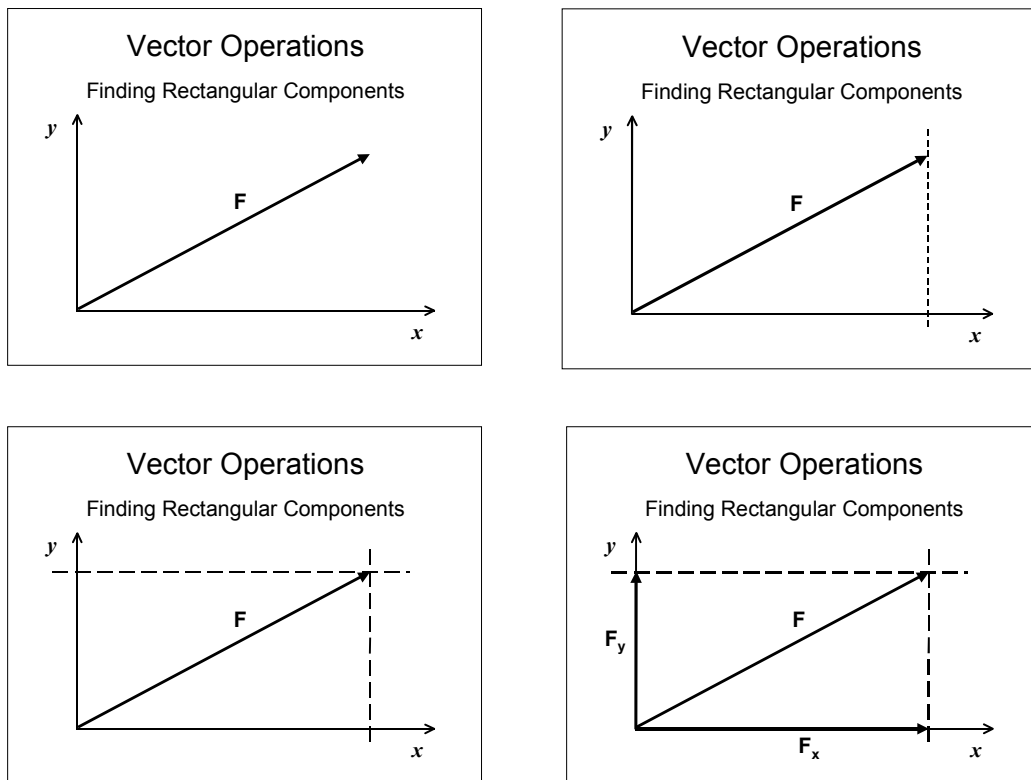


Figure 1: An Animation of Vector Addition Using the Parallelogram Law

It is important to remember that unlike the illustration in Figure 1 above, the student does not see different pictures of the process, but rather watches the elements of the process build up sequentially. This enhances conceptual understanding of the process of vector addition at a deeper level. The animation takes advantage of the capabilities of the new computer technologies being used in the classroom and enhances student interest in the material being presented. This would not be accomplished as easily in a simple chalk-and-board format.

The power of using computer animations in instruction becomes even more pronounced when it comes to showing that the process of resolving a vector into its components is a reversal of the above vector addition process. With the use of an animated presentation, this point becomes easy to make. Figure 2 below shows the sequential steps involved in resolving a vector into rectangular components. If we compare Figure 1 to Figure 2, we can see that the last frame in each of the two sequences looks very similar geometrically. However, by changing the sequence in which the elements of the slides are presented, we change the concept being communicated to the students. In the one case we build up components to get a resultant vector while in the other we break down a vector into its components. The relatedness of the two concepts is made evident by the animation – especially the final slide in each case.



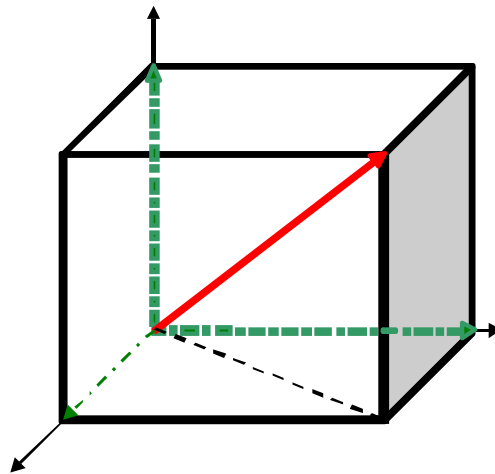
*Figure 2: Animation of Resolution of a Force into Components*

Seeing the two procedures in an animated form helps students to understand the processes involved more clearly. A very important pedagogical benefit to this approach however is that by contrasting the two procedures on the computer, their essential equivalence is illustrated more

clearly than could ever be possible in a printed textbook or in a traditional classroom. Once this conceptual unity is established, developing the mathematical equations for summation of forces using their vector components, becomes straightforward. The equations for resolving a force into its components are established similarly. The physical meaning of the equations themselves is easily interpreted. Most importantly, the similarity of the equations involved becomes much more meaningful to the student.

The above examples were looking at 2-dimensional vectors. In the author's experience, visualizing 3-dimensional vectors is usually very challenging for students who are just starting out on this technical field. Consequently, using computer animations can be a tremendous help to students in understanding how the concepts of vector addition and resolution can be applied in the 3-dimensional environment involved.

One significant disadvantage of using computer animations and physical models is that the students can find it more difficult to take notes as they cannot repeat the animations in their notebooks. Moreover, because the animations are prepared in advance, when they are used in the class, they tend to make the pace of the class faster, putting more pressure on students in their note taking. If the concept being demonstrated is fairly simple, this may not be a major problem. For more complicated animations or models such as those involving 3-d forces, the author has adopted the technique of providing the students with a stripped down version of the relevant animation slide as a classroom handout. Figure 3 shows an example of such a handout for the case of 3-d forces. The students can annotate the handout as the class progresses to keep track of the key points of the lecture. This reduces students' anxiety because they do not have to copy a complicated drawing off the screen and they can pay more attention to the explanations being made in the lecture. This has the additional advantage of keeping the student actively involved in the class while saving on the time required to cover the material.



*Figure 3: Classroom Handout for Analysis of 3-dimensional Forces*

The animation procedure described previously with regard to addition of vectors and their resolution into components can now be applied to 3-dimensional vectors. Figure 4 below shows the sequence of animation frames used to demonstrate the process of resolving a 3-dimensional force into its components. On careful observation, it can be seen that the same idea presented

with the 2-dimensional vectors is being extended to three-dimensional case. By animating the procedure, it is possible to illustrate to the students that the steps involved in the problem solution remain identical whether one considers 2-d or 3-d problems. It is only the geometry that becomes more involved. In this case, an imaginary cuboid is created around the 3-d vector and it is demonstrated that the sides of the cuboid (like the sides of the rectangle in the 2-d case) constitute the components of the vector.

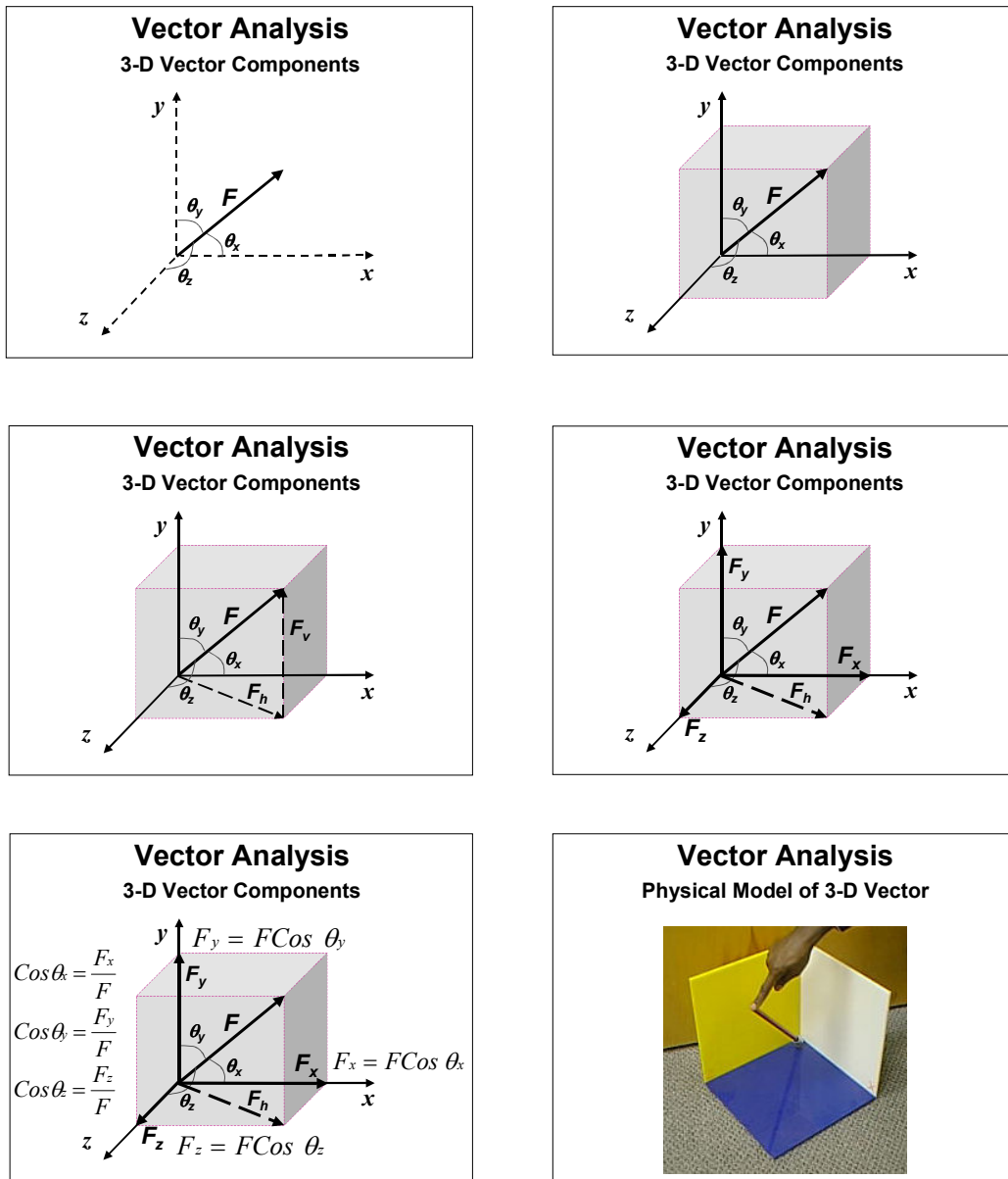


Figure 4: Animation of 3-D Vector Components vs. Physical Model

The animation for finding the components of the vector demonstrates that the procedure for the 3-d problem is conceptually similar to that of the 2-d problem. Thus, although the mathematics

involved in the analysis is more complicated because of the changed geometry, the conceptual unity is more easily communicated to the students as they watch the progress of the animation and compare to that of the 2-d problem. This leads to a deeper understanding on the part of the students and greater confidence in solving problems for all students but is especially helpful to the visual and global learners.

In addition to the computer simulation, the author designed a physical model that is shown to class when the topic of 3-dimensional forces is first introduced. This model is shown in the last panel of Figure 4. The rod to which the finger is pointing represents the vector that can be visualized acting in three dimensions. The rod's orientation in space can be varied freely around its base. This demonstrates to students how the physical orientations of force vectors can vary in space. The use of a physical model like this is particularly helpful in a televised long distance class. The students can get a much better understanding of the topic than would be possible based only on drawings on the board. When it comes to discussing projections of the 3-dimensional force vector into its 2-dimensional components in the three planes shown, the use of the television camera proves invaluable. The camera angle can be changed to show the various projections. With the camera directly above the model for example, the resulting view would represent the projection of the force onto the horizontal (blue) plane. Appropriate camera angles are used to illustrate projections on the other planes.

## Conclusion

The experience gained in developing computer animations and simulations for enhancing instruction in the Statics course was quite valuable. The nature of the materials used in the classroom had to be changed to meet the needs of sensing, visual and global learners. It turns out that these changes were actually beneficial for the more traditional engineering students as well. The use of a largely PowerPoint based delivery made possible the use of slides, handouts and animations in a manner that had not been tried before in this class and students were able to learn more effectively as a result. The end-of-semester student evaluations of the course indicated that all the students liked the changes. Clearly, the use of the new computer technologies offers the students in the course an improved learning opportunity.

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