CAN WE USE A MATLAB APPLICATION TO IMPROVE STUDENT PERFORMANCE ON TRIGONOMETRY OF VECTOR PROBLEM SOLVING?

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Abstract

Vectors are a basic concept for electrical and mechanical engineering and computer science students. To improve the performance of students in classes such as statics, control theory, and computer graphics it is necessary to improve their performance on computing components of vectors. We wrote a computer graphics, animated application in MATLAB to provide students with a method to improve their performance on computing vector trigonometric components. MATLAB is a good choice for doing numerical computations and graphical interface writing; however, the object-oriented animated graphics were difficult to program. We assessed one group of first-year engineering students on vector trigonometric computations who had access to the MATLAB application before the test. We assessed another group of first-year engineering students without access to the application (the control group). Using Student's t-test, the students' mean performance improved at the P = 0.05 significance level.

Introduction

Several faculty who teach mechanical and electrical engineering commented that students are sometimes weak in calculating components of vectors [1,2,3]. This prompted us to do a preliminary test of students in classes taught by one of us. We found that first-year students were weak in trigonometry. Students at University of Technology choose engineering either because they like to do it, for financial reasons or they want to contribute to humanity [4]. Preliminary data in this study, and from teaching experience, suggest that they have some weakness in calculating components of vectors which tends to discourage them from continuing in engineering. The literature on teaching calculating components of vectors is limited to books on vector algebra, and chapters of books on engineering vector mechanics [5]. However, there are many books and papers on teaching secondary level mathematics[6]. Students who received problem-based instruction for two years demonstrated significantly higher mathematics achievement than traditionally instructed students—both in problem solving and in conceptual understanding [7]. Thus, we decided to take a problem-based learning (PBL) approach to increasing student performance in trigonometry of vectors. PBL has been used to teach medicine,

engineering and other subjects [8,9]. PBL refers to teaching by having students use resources such as a computer to solve problems guided by an instructor [10].

Based on this data, we did two things. First, we wrote an animated graphical application in MATLAB to try to help students improve their trigonometry. Second we tested students who had access to the application and tested a similar group of first-year students who didn't have access to the program as a control. The reason we used MATLAB is that it is easy to program in. Due to historical reasons, the animated graphics are somewhat difficult to use. MATLAB is derived from simple FORTRAN [11] which has been in use from 1956 to the present. MATLAB can be traced to Cleve Moler's thesis at Stanford [12]. MATLAB is one of the main products of The Mathworks which was founded in 1984. Mathworks now has approximately 1 million users [13]. Due to MATLAB's derivation from simple FORTRAN, it is a simple and easy to program language; however some of the animated graphics are complicated. Since 1984, the standard for all computers has been the graphical user interface (GUI). The first practical GUI was introduced with the Apple Macintosh. The GUI consists of a mouse or similar device which is used to point to buttons on the computer screen and, in our case, choose the angles to calculate trigonometric values.

The main idea of this paper is to propose an animated graphical vector simulation to improve engineering and technology students' command of trigonometry and, thereby, the calculation of components of vectors.

Educational Plan

Starting in the spring of 2013 we tested students on their ability to calculate the horizontal component of a vector. Students were asked to use trigonometry to calculate the horizontal component of a vector "by hand" and then compare their results to an animated problem solution calculator. Animation is often used (e.g. Working Model engineering education software [14]) to stimulate student interest. In this preliminary study, we animated a vector rotating describing a unit circle. We tested the students on calculating the length of the shadow of a leaning tree (see diagram in Appendix A). This testing method produced tentative results which indicated that first year students seemed to test low on their ability to calculate one component of a vector.

We continued in the fall of 2013. In the second study, we focused on determining whether using an animated MATLAB solution calculator would quantitatively improve first-year students' performance. The solution calculator was rewritten to animate a rocket flying straight up. It's altitude was calculated by a laptop computer running the MATLAB application with various elevation angles chosen by the student. We tested the students on calculating the height of a building given a base-line and elevation angle (see diagram in Appendix B).

The main idea of this paper is to measure the improvement in first year students' performance due to the use of an animated solution calculator. We chose to implement the solution calculator

in MATLAB (see Appendix C for a flow-chart of the graphical user interface for the solution calculator).

Methods

During the 2013 spring semester, one of us (Caserta) tested first-, second-, third- and forth-year students in Engineering Technology, both students and advisees. These students were given a test of their ability to calculate the components of a vector. This involved calculating the horizontal component of a vector. The vector was the length of a leaning tree measured along the tree at the angle of elevation. The horizontal component was the horizontal length of its shadow with light coming vertically down from the sun (see Appendix A). The purpose of this test was to do a preliminary test of our students' possible weakness in calculating the components of vectors.

During the 2013 fall semester, two of us (Ma and McCusker) taught first-year engineering students in Introduction to Engineering. Students were exposed to an animated horizontal component calculator application coded in MATLAB (see Appendix A). All sections of Introduction to Engineering, including more than 125 students were tested. The vector component calculation test was administered to these engineering students. (See Figures 1 and 2 for a summaries of their responses.) This test assessed the first-year students since, in the earlier preliminary study, they seemed the weakest group. Furthermore, we thought that the first-year engineering students were at risk for failure in statics, control theory and computer graphics since calculating vector components is fundamental to learning these subjects.

At the end of fall 2013, one of us (McCusker) administered a second test to his students. In this test the students were asked to calculate a vertical component (height of a building), given the horizontal component (base line) and angle of elevation of the top of the building (see Appendix B). One section was given access before, but not during, the test to an animated, computer graphics altitude calculator coded in MATLAB and the other control group wasn't given access. (See Figures 1 and 2 for a summary of their responses.)

The tests did not record the gender or socio-economic status of the students.

Discussion of Results

The preliminary results indicated that freshmen have some weakness in the analysis of vectors, particularly in the area of resolving vectors into components (see Appendix A). In the preliminary study, first-year students usually could not answer the test question, while seniors could. This basic calculation of vector components is essential for applying vectors to problems in several engineering disciplines. Some of our University's engineering students have reasons other than interest in mathematics for studying engineering [4]. So, the low performance of freshman on vector calculations was as we would have predicted.

In the second study, first year students' performance on another vector component problem (see Appendix B) was graded A,B,C,D or F. A grade of A was assigned for correct answers. B was the grade assigned for a correct answer with incorrect units. C was assigned if the answer was wrong due to wrong arithmetic. D was assigned if the answer showed awareness of basic trigonometry. A grade of F was assigned if the student gave no answer. Numerically, A=5, B=4, C=3, D=2, and F=1. The results without the application are shown in Fig. 1. The average is 3.97. The results with the application are shown in Fig. 2. In Fig. 2, we see that there is a large improvement for students with access to the animated graphics application, since the average is raised to 4.66. Using Student's T-test, we found the difference in the means significant at the P=0.05 level [15].

Conclusions

To improve the performance of students in classes such as statics, control theory, and computer graphics it is necessary to improve their performance on computing components of vectors. We wrote a computer graphics, animated application in MATLAB to provide students with a method to improve their performance on computing vector trigonometric components. MATLAB is a good choice for doing numerical computations and graphical user interface (GUI) writing; however, the object-oriented animated graphics were difficult to program. We assessed one group of first-year engineering students on vector trigonometric component computations who had access to the MATLAB application before the test. We assessed another group of first-year engineering students without access to the application (the control group). Using Student's t-test, the students' mean performance improved at the P = 0.05 significance level.

We suggest that in the future a physical lab might be incorporated with the computer simulation (e.g. a game to be played by the students where they physically manipulate game pieces representing vectors). More study is needed to determine the best game to teach vector mathematics to engineering and technology students.

Acknowledgement

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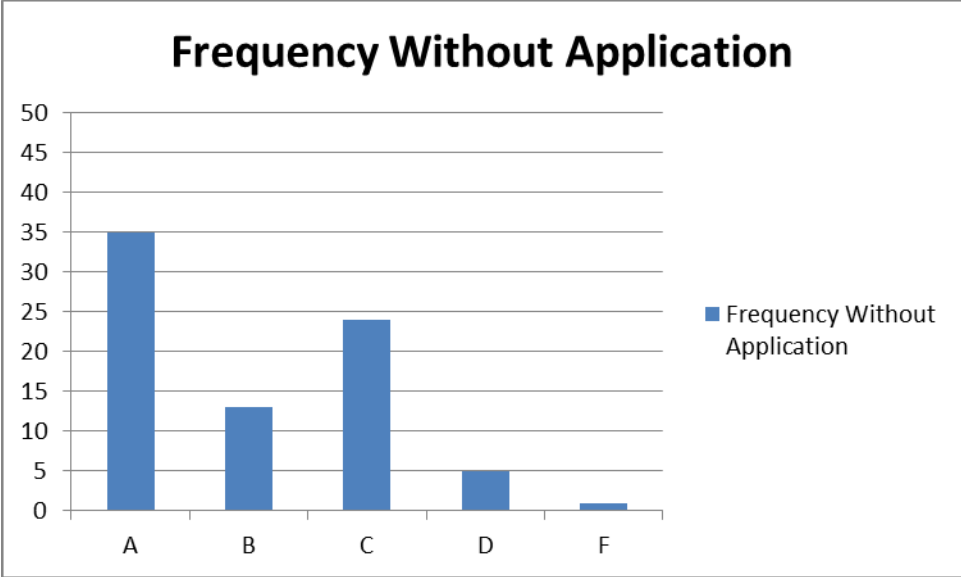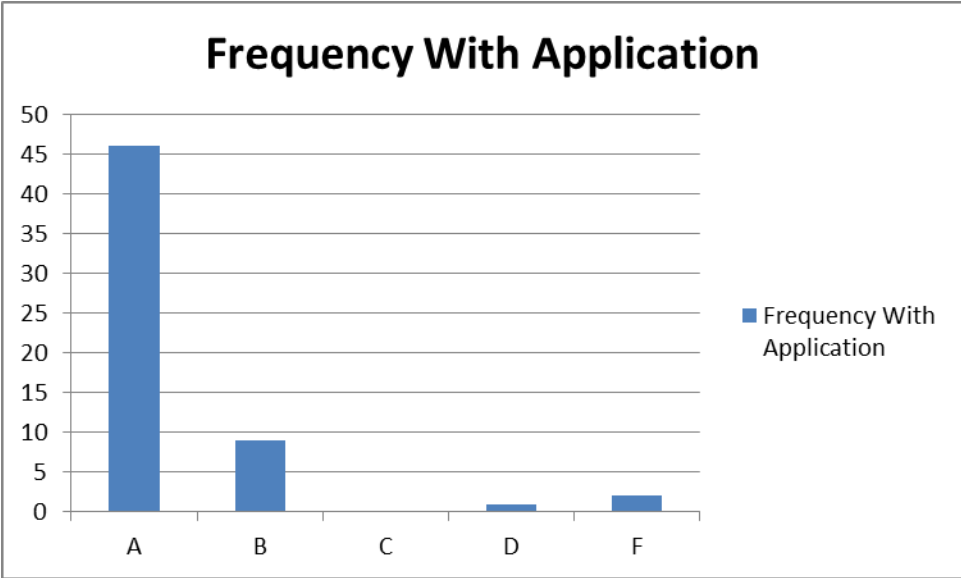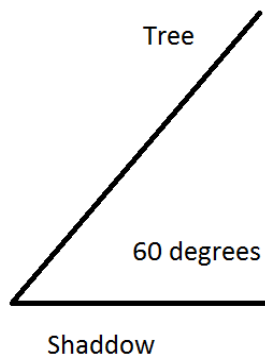[15] Rickmers, Albert and Todd, Hollis, *Statistics*, McGraw Hill, New York, 1967

Fig. 1

Fig. 2

Appendix A Educational Research Question: Find the horizontal component of a vector given the magnitude and angle of elevation of the vector

A 1m tree is leaning at a 60 degree angle. The sun is directly above it. Find the length of its shadow.

Tree

60 degrees

Shaddow

Appendix B Educational Research Question: Find the vertical component of a vector given its horizontal component and angle of elevation

A new international trade building has been built in New York City. An engineer sights the very top of the building from 1025.4 feet away at a 60 degree angle to the horizontal. Find the height of the building.

x = height of building

60 degres

1025.4 feet
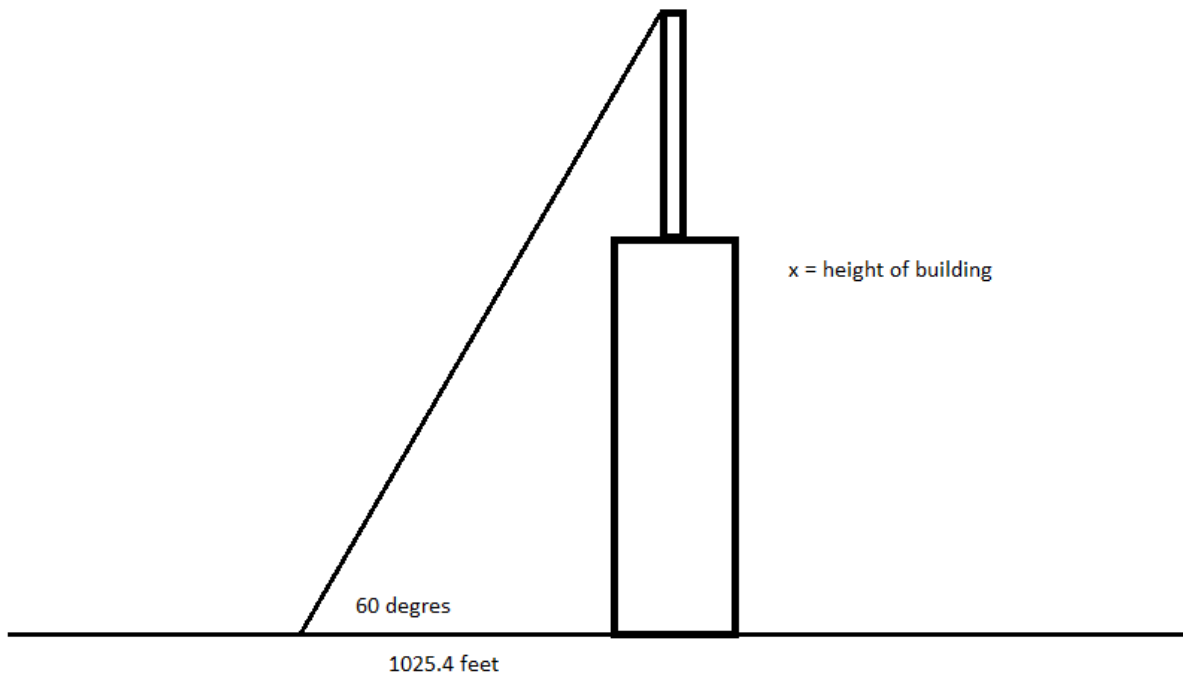
Appendix C – Flow Chart for Computer Animated Application GUI