# Creation of an Online Vector Addition Tutorial: Exploring the Advantages of Providing Diagnostic, Multilevel Feedback in Basic Skills Remediation

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Abstract

Student deficiencies in introductory concepts such as vector addition can hinder their ability to advance in successive courses. While dedicating class time to the concept can be of some assistance, the ability to practice in a positive environment that provides immediate feedback could be significantly more instructive. Online tutorials provide an out-of-class mechanism for students to learn key concepts. If tutorials are well crafted they will help students to learn from the mistakes that they make. The vector remediation module is designed to assist students in the process of adding two vectors in the context of a biomechanics problem. The Courseware Authoring and Packaging Environment[1] software (CAPE) supplies a diagnostic correction mechanism that identifies common student errors and provides specific feedback based on the type of mistake encountered. Each student is given three chances to answer the question properly. The type of feedback becomes more specific as the number of incorrect responses increases. Some common student errors, such as reversing the components of the vectors, are diagnosed within the software and specific feedback is provided to the student. However, if the student error does not match any of the common errors, a more general diagnostic path is offered through the tutorial. The vector remediation module will be used in an introductory biomechanics course at Vanderbilt University. It will be tested to see if it increases the ability of students to perform vector addition on homework and exams, and to determine if the time spent in reviewing vector addition in the classroom can be reduced.

## Introduction

As more course materials become available to students via courseware management websites, online tutorials are becoming an increasingly important component of the course material delivered to college students. These often take the form of PowerPoint slide shows including lecture material or examples of important concepts that have been taught, or will be taught in class. The student progresses through the slides in a linear manner from the predetermined start of the material to its conclusion. The vector remediation module has been designed to be used in combination with a vector tutorial that reintroduces students to vector math.

In order to ensure that students have both the knowledge and the comfort level with vector operations that will facilitate their future success in biomechanics coursework, an online remediation component is being incorporated into a larger tutorial in vector operations. This remediation is a more robust tool for enhancing student learning than a traditional tutorial because students' paths are not limited to a linear progression through the information. Each answer presented by a student is evaluated and assessed and an appropriate correction scheme is provided allowing students to learn from the specific error that is diagnosed.

A software authoring environment, CAPE, has been developed at Vanderbilt University to provide the tools for developing interactive problem sets which can be accessed through a courseware management website. CAPE is a visual coding language where blocks that represent various coding operations such as boolean operators are connected to create conditional branches. Sets of blocks are then organized into modules. CAPE also has an area where specific constants and calculated values can be written or where pieces of scripted code can be used to create functions that would be cumbersome to code visually.

Recent research in learning science such as the How People Learn (HPL)[2] model provide the general learning science principles underlying the development of the remediation. Through the tutorial, the specific misconceptions that a student has about the solution technique for a problem are identified and corrected. The students are provided with immediate formative feedback based on their mistakes so they can make corrections immediately.

Methods

The test bed for the vector remediation and tutorials was a sophomore-level introductory biomechanics course, BME 101. Students in the class completed a six-question pretest in vector math on the first class day of the spring semester 2003. The first question asked students to break two vectors into X and Y components. The second questions asked them to subtract the two vectors. The third question asked them to calculate the magnitude and direction of the vector resulting from the previous vector subtraction. The fourth question asked them to calculate a unit vector in the direction of one of the vectors. The fifth and sixth questions asked them to make a calculation using a dot product and a cross product respectively.

Students were then asked to complete the vector tutorial, the vector addition remediation module and a posttest before the next class (two days later). During that time they were instructed to use no materials but the vector tutorial and vector addition remediation module. Posttests were completed online via an electronic learning management system.

The vector tutorial is a series of approximately 60 PowerPoint slides that demonstrate, both with words and schematics, basic vector operations. The presentation begins with a very simple exercise in thinking about the differences between vectors and scalars. It then demonstrates how to calculate a vector between two points, how to construct unit vectors, how to multiply a vector and a scalar, and how to calculate the components of a vector give its magnitude and direction.

The tutorial then progresses through a series of examples of vector addition, subtraction, vector multiplication, and direction cosines. Each student was allowed to view the presentation only one time between the pretest and the posttest.

The vector addition remediation module has five specific pathways that are identified as sources of potential student errors. Figure 1 provides a schematic diagram of the underlying logic for the remediation.

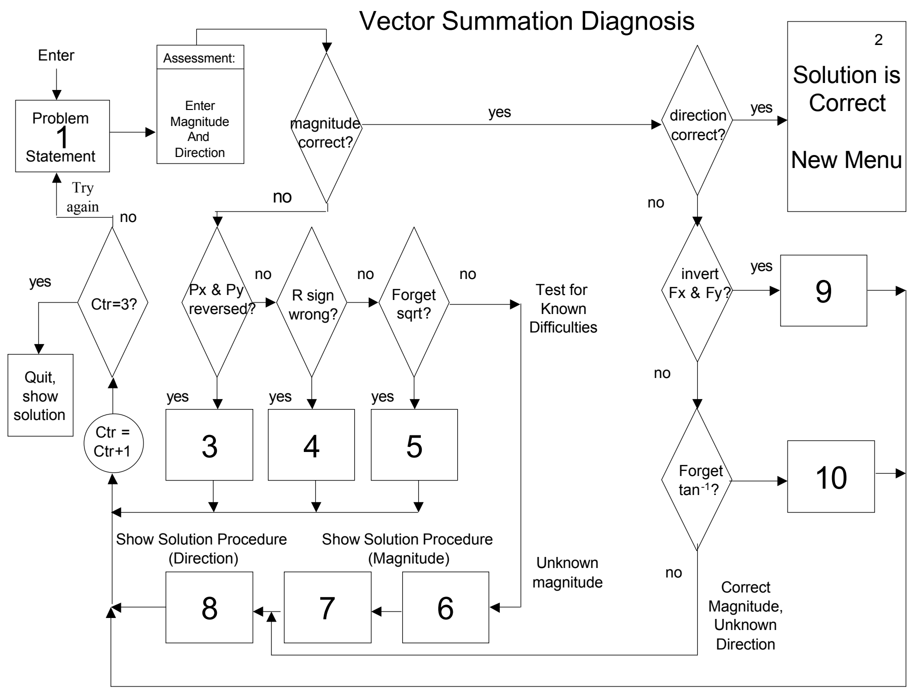


**Figure 1: Flowchart showing the basic logical structure of the vector addition remediation module. Diamonds represent the evaluation steps, while squares indicate that a slide is shown to the student.**

The most frequent sources of error have been identified by one of the authors through his many years of teaching introductory biomechanics. Each pathway contains specific corrections to raise the students' awareness of the error.

Students using the vector remediation are presented with a problem statement asking them to add forces acting on a red blood cell. The values are randomized so each student is presented with slightly different values with which to make calculations. The student is then asked to provide the correct magnitude and direction of the sum of the two vectors. The student answer is evaluated based on computations made within the software. Depending on the answer, the student will be given a correction for the mistake they have made, or will be told that they have solved the problem correctly. The student is given three opportunities to correctly answer the question before a complete solution is presented. Each time the student submits an incorrect answer, the specificity of the correction that is presented increases. Figure 2 is indicative of the type of feedback that would be provided to a student following their first incorrect response.

It looks like you may have forgotten to take the arctangent when computing the angle.

**Figure 2: If a student has given one incorrect response, the assessment slide would be a word slide. This slide is used if the student has not taken the arctangent of the components when evaluating the direction of the resultant vector.**

Phase two correction slides, those that the student views after a second incorrect response, have an increased level of specificity. These slides normally provide a diagram in addition to words. Figure 3 shows the phase two slide corresponding to the phase one error slide shown in Figure 2.

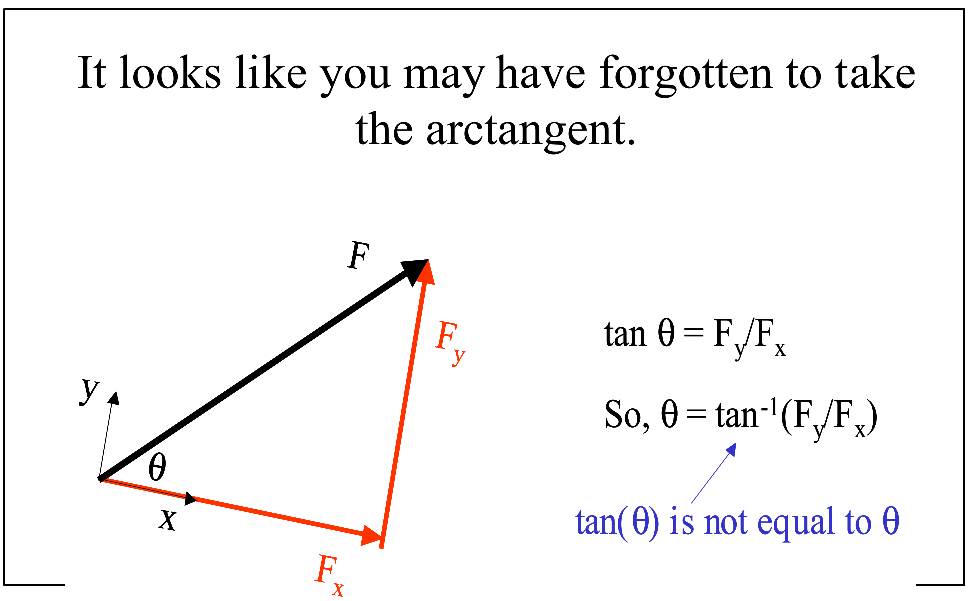


**Figure 3: If a student answers the question wrong on his second attempt, this is a slide representative of the feedback that he would see.**

If the student answers the question incorrectly on his third attempt, a complete solution is provided. Figure 4 shows a screen capture of a phase three correction slide.

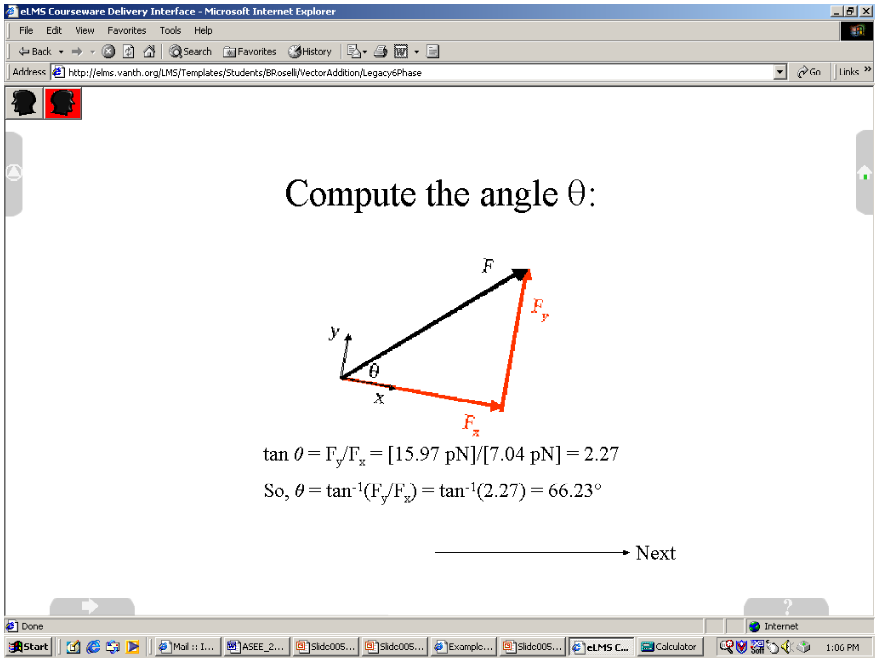


**Figure 4: This is a screen capture of the Phase 3 solution. This is shown to the student if he has given three incorrect responses to the initial question.**

Results

Thirty-three students in the BME 101 class completed both a pretest and posttest. Figure 5 demonstrates the results for each question on the pretest and the posttest. A paired t-test was used to determine those systems where the change in student performance was statistically significant ($p<0.05$). An asterisk next to the appropriate question number denotes statistically significant differences.

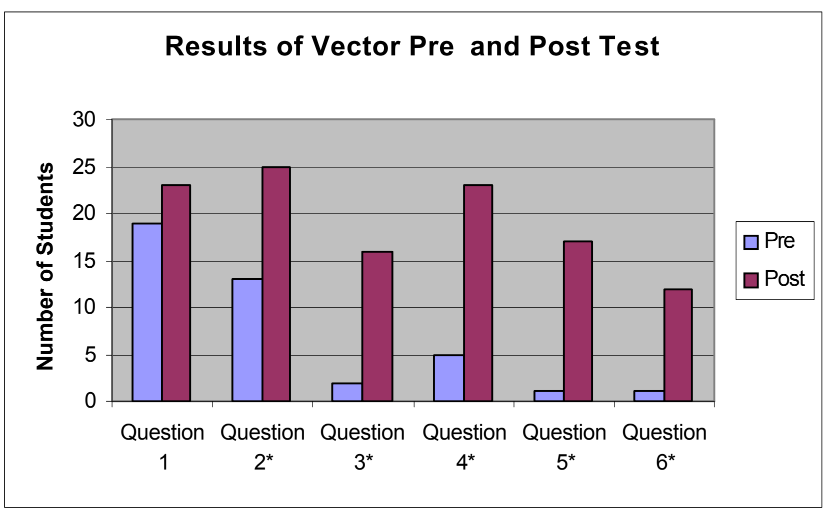


**Figure 5: Comparison of Pretest and Posttest results. Asterisks signify that there was a statistically significant difference for that question.**

## Discussion

The pretests indicate that few students were able to perform basic vector math. The majority of the students (19 out of 33) were able to break vectors into X and Y components. Not surprisingly, there was only a modest increase in this number (23 out of 33) on the posttest. The most common error on both the pretest and posttest in this area seemed to be using the wrong angle to calculate components.

Students had the most difficulty with the vector multiplications. On the pretest, only one student could correctly calculate the dot product and one could calculate the cross product. The most common error on the pretest was not answering the question (18 for the dot product, 21 for the cross product). On the posttest, students made significant gains (17 answered the dot product correctly, 10 answered the cross product correctly). Errors on the dot product question were difficult to analyze on the posttest. The most common error on the cross product involved having components in inappropriate directions.

The vector addition remediation specifically targeted the skills needed to answer the first three questions. As such, the modest, but statistically significant increase on the third question (where students were asked to calculate the magnitude and direction of the resultant vector from problem 2), was somewhat disappointing. A potential cause of this relatively small rise could be due to the fact that the vector addition remediation used by the students in January was only applied in the first quadrant. The problem on both the pretest and the posttest had a resultant angle in the third quadrant. Nine students calculated the resultant angle in the wrong quadrant on the posttest. Interestingly, quadrature information was provided in the tutorial, but seemed to go largely unnoticed by the students.

Overall, the results seem to suggest that the introduction of out of class materials gave students the tools to make substantial gains in performing basic vector operations within a short period of time. With the exception of the first question, students made statistically significant gains on all the questions. Though we have no way to directly measure the gains that can be attributed the remediation as opposed to the tutorial these results validate the effort that was put into developing these materials for out of class use.

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## Bibliography

1. Howard LP. Courseware and Packaging Environment (CAPE). http://www.isis.vanderbilt.edu/projects/VaNTH/index.htm
2. Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds). (1999). How People Learn: Brain, mind, experience, and school. Washington, DC: National Academy Press.

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