Project Summary:

The main goal of this project is to improve student understanding of the geometric nature of multivariable calculus concepts, i.e., to help them develop accurate geometric intuition about multivariable calculus concepts and the various relationships among them.

To accomplish this goal, the project includes four parts:

- Creating a Multivariable Calculus Visualization applet using Java and publishing it on a website: web.monroecc.edu/calcNSF
- Creating a series of focused applets that demonstrate and explore particular 3D calculus concepts in a more dedicated way.
- Developing a series of guided exploration/assessments to be used by students to explore calculus concepts visually on their own.
- Dissemination of these materials through presentations and poster sessions at math conferences and through other publications.

Intellectual Merit:

This project provides dynamic visualization tools that enhance the teaching and learning of multivariable calculus. The visualization applets can be used in a number of ways:

- Instructors can use them to visually demonstrate concepts and verify results during lectures.
- Students can use them to explore the concepts visually outside of class, either using a guided activity or on their own.
- Instructors can use the main applet (CalcPlot3D) to create colorful graphs for visual aids (color overheads), worksheets, notes/handouts, or tests. 3D graphs or 2D contour plots can be copied from the applet and pasted into a word processor like Microsoft Word.
- Instructors will be able to use CalcPlot3D to create lecture demonstrations containing particular functions they specify and/or guided explorations for their own students using a scripting feature that is being integrated with this applet.

The guided activities created for this project will provide a means for instructors to get their students to use these applets to actively explore and "play" with the calculus concepts.

Paul Seeburger, the Principal Investigator (PI) for this grant project, has a lot of experience developing applets to bring calculus concepts to life. He has created 100+ Java applets supporting 5 major calculus textbooks (Anton, Thomas, Varberg, Salas, Hughes-Hallett). These applets essentially make textbook figures come to life. See examples of these applets at www.monroecc.edu/wusers/pseeburger/.

Broader Impacts:

This project will provide reliable visualization tools for educators to use to enhance their teaching in calculus and also in various Physics/Engineering classes. It is designed to promote student exploration and discovery, providing a way to truly "see" how the concepts work in motion and living color. The applets and support materials will be published and widely disseminated through the web and conference presentations.

Student Guided Explorations/Assessments:

A series of guided explorations/assessments are being created to help students to gain a deeper understanding of the geometric nature of various concepts in multivariable calculus. Some of these explorations will also be used to help assess the effectiveness of the visualization tools and the explorations themselves at improving student understanding of various concepts. If you have ideas for future assessment topics and/or questions or functions to explore, please contact Paul Seeburger at pseeburger@monroecc.edu.

So far, the following three explorations have been completed:

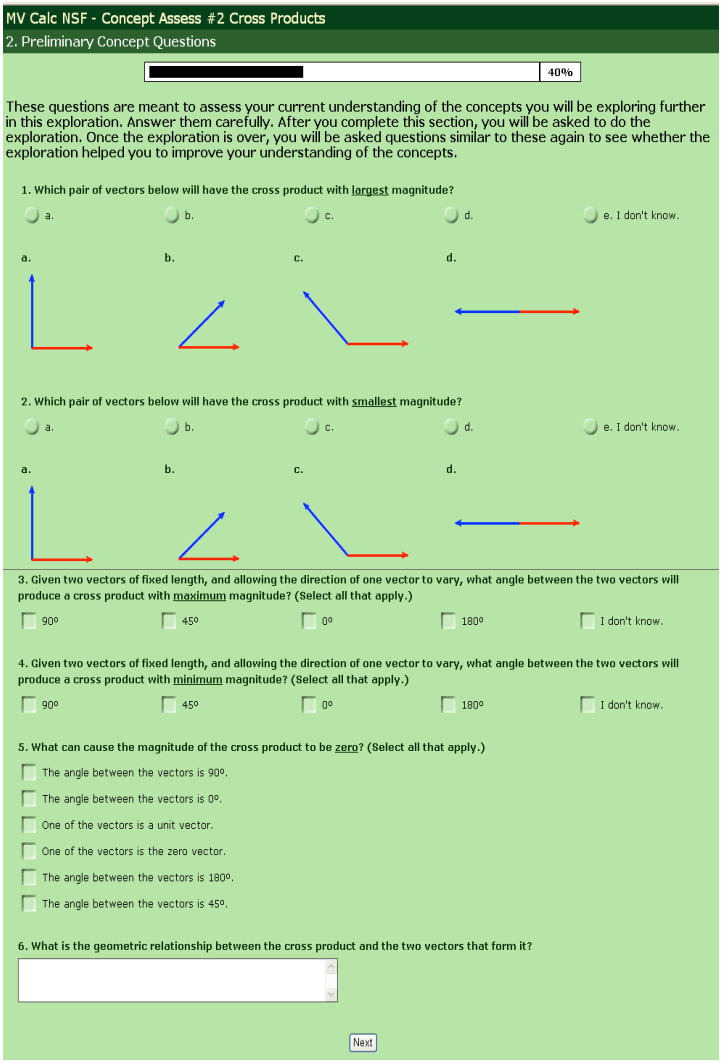
- **Dot Product Exploration**
- **Cross Product Exploration**
- **Velocity and Acceleration Exploration**

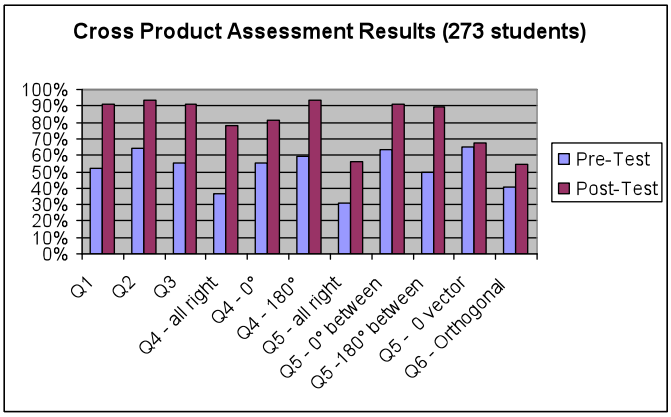
The following explorations are in the process of being created this semester:

- **Lines and Planes in Space Exploration**
- **Contour Plots Exploration**
- **Lagrange Multipliers Exploration**

Each of these guided explorations have been created with SurveyMonkey to make it easier to collect student response data. Students are asked a short series of Pre-Test questions before they complete the body of the exploration. A link to the applet is provided in the survey which also supplies the script for the actual exploration in the CalcPlot3D applet. After the students complete the actual exploration using the applet, for which there is a second list of questions in SurveyMonkey to complete, they are asked a series of Post-Test questions which are very similar to (or sometimes the same as) the Pre-Test questions.

As you can see below, the results have been quite positive. For example, student success on the Cross Product Exploration went from roughly 60% or less on the Pre-Test questions to 90+% on six of the Post-Test items.





Explore these exploration-assessments yourself by clicking on the **Workshop/Faculty** link on the left sidebar of the project website. These faculty links allow you to explore the assessments while keeping your results separate from student data.

Invitation to Participate:
Please consider using these materials with your calculus classes! Also recommend them to anyone who might be interested in using them, including faculty in Mathematics, Physics, or Engineering.

If you would like to participate in class-testing the materials for this project and be involved in their continued assessment and improvement, or if you simply have some comments, questions, or suggestions concerning this project, please contact Paul Seeburger at pseeburger@monroecc.edu.

To access these materials go to:
http://web.monroecc.edu/calcNSF