

ENLIVEN YOUR MATHEMATICS COURSES USING DEMOS AND PROJECTS

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Introduction

Demos and projects, widely accepted as useful tools to aid in student learning, augment traditional instruction within a student-centered classroom. [See **Student-Centered Classroom** references in the resource collection.] Emphasis on the development of demos and projects has increased in journal articles [See **Demos and Projects Journal Articles** in the resource collection.], in the minicourses offered at professional meetings [See **Conference Proceedings** in the resource collection.], and in contributed paper sessions at professional gatherings such as MAA/AMS national and sectional meetings, ICTCM, etc. In order to make effective use of demos and/or projects, an instructor may need to modify the style in which topics are presented and use care in selecting the demonstration to be presented and be careful to select a project that complements class work. The inclusion of demos and projects requires careful planning of what we present and of how we use classroom time. To incorporate these activities requires a careful balance of various styles of communication.

In this article we look at two by-products of instruction; the immediate impact of a classroom demo and the more individualized synthesis of a group of ideas provided by projects. The primary objective of both demos and projects is to aid students in understanding mathematical concepts. Classroom demos related to a single topic provide opportunities for instructors to get and to maintain student interest, while providing a foundation on which to build. Once we have engaged the students' attention, we can use a demonstration to draw them into active oral participation. This interaction helps to break down some instructor-to-student and student-to-student communication barriers. Students oriented projects, done individually or in small groups, encourage more intimate interactions between students and a set of mathematical ideas. Projects foster a cooperative attitude among students in a problem-solving environment, a major contribution to the learning process. Such experiences provide exposure to on-the-job realities that students will face. A combination of demos and projects creates a lively and interesting learning environment.

Classroom Demos

Demos can be incorporated in an instructor's presentation to make the classroom more student-centered. The use of demos in the context of active learning is consistent with many aspects of reform in undergraduate mathematics education, including the utilization of instructional technology. Technology equipped classrooms are now common in both

large and small formats and provide the opportunity for meaningful demonstrations that contribute in a positive way to student understanding. *In any form of instruction, effective demonstrations that accompany the ideas and concepts are essential.* Presenting information in a manner that fosters an intuitive understanding of concepts is perhaps the greatest challenge of mathematics instruction.

Instructors need to establish an environment that encourages active participation by students and to find additional learning tools that work well. It is widely recognized that the instructor has an important role in the student-centered classroom as a facilitator for communication of ideas and for establishing and maintaining the focus of the students.

Demos can be

- 1) used in a wide variety of the mathematics courses,
- 2) geared toward what the instructor does in a classroom presentation,
- 3) formulated to engage students in problem-solving situations,
- 4) used to establish lines of communication within a classroom, and
- 5) useful in pinpointing conceptual difficulties based on student reactions.

Experienced instructors have private toolboxes of demos, conceptual approaches, or physical gadgets they use to encourage students to tune-in to mathematics. This rich, but largely untapped resource of tried-and-tested ideas forms the basis for *Demos with Positive Impact*, an NSF funded project that is building a web-based database of instructional demos and connecting this resource to mathematics instructors. This project takes advantage of the knowledge and the experience of colleagues across the country and presents these valuable resources to the mathematics community in an attractive, user-friendly format. *Demos with Positive Impact* is a resource for instructors who are looking for ideas or demonstrations adaptable for various teaching styles and learning environments. The URL for *Demos with Positive Impact* is

<http://www2.gasou.edu/facstaff/lroberts/demos>.

In building the collection within *Demos with Positive Impact* we have tried to carefully communicate the information supplied by contributors regarding background, introductory foundations, delivery techniques, devices for engaging students in discussions, and the reaction to and the response of students to the use of the demonstration in class. While each instructor can create a “tailor-made” presentation that incorporates a demo, there are certain common features that successful demos share. For example,

- The demo is short and focused on a particular idea or concept.
- There is a sense of drama or mystery with a touch of humor.
- Visual components are used to complement an instructor's verbal description.
- Color and simplicity are assets.
- A step-wise progression of components develops the demo.
- The speed at which a visualization component progresses is slow enough for students to simultaneously assimilate an instructor's dialogue. Or, the demo can be rerun with little effort.
- There is ample time for student questions or remarks along the way or repetitions of parts of the demo are easy.

- In some sense, the demo is open ended; that is, the demo, or a generalization of the demo will recur throughout the course so that the demonstration tends to have a lifetime longer than a single class.

Ideally, a student should be able to run the demo on his or her own. A replay of the demo can refresh or even provide a more detailed examination of the concepts examined during the class. Hence, any technology platform employed by the demo should be accessible to the student, unfortunately, this is not always possible or practical. To help to overcome this difficulty, a recent initiative of *Demos with Positive Impact* has been development of browser capable versions of demos that were originally in a program dependent form. These browser-based demos utilize Javascript, Java, and animations in movie form (avi or mov format) or animated gifs. An important aspect of this NSF project is to involve students in development of materials, and we have been particularly successful in this area by having students create applets for a number of demos.

In many cases there is a fine line between a demo and a project. In fact, demos are perfect ways to introduce a project. One group of demos in the *Demos with Positive Impact* collection relates to the use of the Monte Carlo simulation method, a technique for approximating probabilities associated with a physical experiment without performing the actual experiment. Because the Monte Carlo technique is commonly used to solve problems and is conceptually easy to present, it provides a good introduction to probability. In fact, there is no need to try and explain the general concept a priori because the experience students get from a few experiments often lays sufficient foundation for them to see how the technique applies in a variety of situations. These demos are very nice because they can be presented in lower level classes and because they provide the background for investigations that make good projects for groups or individuals. In addition, these demos include platform independent interactive Java applets to accompany them. Five demos in this group include

- **Area Estimates by Monte Carlo Simulation:** an introductory experiment for estimating the area of a circle,
- **Pump Simulation:** a network simulation that utilizes a 0-1 spinner,
- **Chocolate Chip Allocation:** an experiment in which a fixed number of chocolate chips are distributed among 100 cookies,
- **Bacteria Allocation:** an allocation simulation that randomly allocates bacteria to a fixed number of droplets from a total of 100 droplets,
- **Simulation of a Rainbow:** a simulation of the generation of a rainbow.

Using platform-independent Javascript slide shows the demo, “Taylor Polynomials—A Visual Approach to Approximations” is a nice introduction to the general problem of approximating a function by a polynomial. The demo provides visualization of several functions function and their approximating Taylor polynomials centered at $x = a$. In addition, there is an option that displays the error function in the neighborhood of $x = a$. This demo can be used in calculus courses where Taylor polynomials are first introduced, or in numerical analysis courses where a more detailed study of approximations is covered. Interactive routines are provided for several popular mathematical software packages such as *Mathematica*, Maple, and Mathcad.

Course Projects

A course project, an important tool in active learning, can be used to advance the instructor's presentation and to clarify concepts as part of an in-class or an outside-of-class student-centered learning experience. A project provides an opportunity for students to focus on and to explore the course material and course concepts for a longer period and in greater depth. Projects provide a forum for student discussion of concepts, increasing student interaction with peers and with the instructor, promote active involvement in learning concepts, and increase engagement and interest in course topics. Projects, mostly out-of-class experiences, reinforce student learning and increase students' retention of course material while promoting higher order thinking. Course projects, both small and large, make in-class learning more real as students are directed to analyze how course topics are related to situations in real life.

Projects, individual or group, can be used to enable students to learn a variety of skills while enhancing student learning. Through projects, students can improve basic thinking skills, analytical, and problem-solving skills, develop decision-making and conflict management skills, and enhance social and communications skills. Projects provide students with a situation that necessitates their taking on the role of teacher as they interact with peers in an effort to analyze and to resolve the project question or problem.

Projects provide an opportunity for students to learn and to use technology. As part of a project, students may use the World Wide Web as a tool in research or as a source of data or general information. They may use mathematics software such as Derive, Maple, MATLAB, or Mathematica or graphing calculators to perform analysis, modeling, or simulations. In addition, project presentations provide opportunities for students to learn and to use presentation software such as MS PowerPoint and a variety of equipment such as computers and LCD projectors, document cameras, digital cameras, and smart-technology whiteboards to create and to share project analysis and solutions with peers and with the instructor.

While project topics are varied, successful projects share several common goals and features. These include but are not limited to

- requiring greater out-of-class student involvement than simple homework assignments,
- activities and/or research that require students to think about what they are learning,
- relating course material to real life,
- application of course material to define, to analyze, to synthesize, and to create a solution for a realistic problem,
- simulation and modeling, and
- communicating mathematics using presentations, reports/papers, or web pages.

In many cases, projects provide students an opportunity to view the mathematics that they are learning as meaningful and useful. For example, many students taking General Mathematics, College Algebra, or Precalculus courses have difficulty in applying functions and in particular, piecewise functions. The project "How Good Is Your Cellular/Wireless Phone Plan?" provides students with a situation in which to apply their

developing knowledge of functions and a realistic use of piecewise functions as they analyze, model, and compare a variety of cellular phone plans with their own wireless phone plan in an effort to determine if their cell phone plan is the most economical for their phone usage. As part of this project, students use the World Wide Web to research wireless phone plans and they use a variety of software as they write the project paper and create an in-class presentation of their analysis and conclusions. The project takes advantage of the popularity of wireless phones to allow students to practice and to apply their knowledge and to experience how mathematics and functions in particular can be used in analysis that can help the consumer.

Some projects can be used for a wider variety of courses. The project “A Trip To The Circus”, analysis of a human cannonball shot, can be used in General Mathematics, College Algebra, Precalculus, Calculus I, Calculus II, and Multivariate Calculus. The project with its humorous side is based on “flight” information of a real human cannonball, David “The Bullet” Smith who holds the Guinness World record for the longest human cannonball shot (181 feet in June 1998). The project with its underlying problem is presented as a narrative that the students must complete. In the narrative, the students find themselves attending a circus performance at the Fleet Center in Boston, Massachusetts where they, as members of David “The Bullet” Smith’s team must determine “flight” information requested by the audience as part of David’s interactive performance. As part of this project, students must find and define the underlying problem, gather relevant information, determine the appropriate constraints, and create and synthesize a detailed solution. All analysis and the appropriate solutions are presented in the continued narrative along with explanation of the relevance of the mathematics used to determine the solutions.

Summary

Demos and Projects reinforce learning through in-class and outside-of-class student-centered learning experiences. Demos, usually related to a single topic, help instructors to engage students, help students to focus on mathematical concepts, and draw students into learning. Projects provide more active involvement in learning and in applying concepts while demonstrating the relevance and usefulness of course topics through sometimes artificially constructed but real situations. Both demos and projects expose students to useful technology and make classroom learning more genuine, causing students to contemplate what they are learning and how it relates to life.

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Resource Collection

A growing collection of resources, including those cited in this article, is available at the URL <http://www.cs.gasou.edu/faculty/demos/papers/ICTCM14/resources.html>.