

# Graphing Projects with Desmos

Throughout their high school careers, students learn to graph a variety of functions and equations. In entry-level mathematics courses, students learn the general shapes of a number of different functions; in upper-level mathematics courses, they also learn about transformations, piecewise functions, restricted domains, and graphing inequalities.

The following project incorporates all these topics. Students create an artistic design that uses parts of a number of different graphs. By completing this project, students learn to graph the general shapes of parent functions (or reinforce their knowledge of how to do so), to transform these shapes, and to

use a restricted domain or range to use a specific portion of a graph.

A wide range of programs, apps, and hardware that allow completion of this project is available, but many are limited in their scope or functionality. Some programs are limited in their graphing capabilities; others may not be used on any computer or tablet; and others are so difficult to use that the task would entail more time learning the program than learning the mathematics associated with the graphing. An exciting new website has recently been launched that allows teachers and students to do everything required by this project and more.

Desmos is an online graphing utility that requires no downloads or special hardware. It works on any computer, tablet, or phone. The website updates automatically and does not require any uploads. In addition, a Desmos iPad® app is available with the same functionality as the online version. Best of all, it is free! Teachers and students can begin graphing right away at [www.desmos.com](http://www.desmos.com). Although signing up for a free account is not necessary, doing so will allow users to save, email, embed, or print projects.

## GETTING STARTED

To start using Desmos, visit [www.desmos.com/calculator](http://www.desmos.com/calculator) and simply type

any expression. For example, entering  $2x - 5$  will graph the linear equation  $y = 2x - 5$ . Braces can be used to restrict a domain or range. Entering  $-x + 8$   $\{-3 < x < 3\}$  will graph the portion of the line  $y = -x + 8$  between  $-3$  and  $3$ . Graphing a vertical line is as simple as entering  $x = 4$ . Implicit functions can be graphed by entering their equations—for example, entering  $x^2 + y^2 = 25$  will graph a circle. Points can be graphed by entering their coordinates, such as  $(-7, 1)$ . Inequalities can also be graphed by entering them—for example,  $y > x^2$  (see **fig. 1**). Desmos will graph any function with transformations, implicit equations, polar and parametric functions, and piecewise functions.

To make graphs more dynamic, parameters can be used instead of constants. Desmos will detect parameters as they are entered and give users the option of creating a slider. Entering  $a(x - h)^2 + k$  gives the option of adding sliders for each of the parameters  $a$ ,  $h$ , and  $k$ . Adjusting these sliders will immediately affect the shape of the graph of  $y = a(x - h)^2 + k$  (see **fig. 2**). This type of exploration allows students to instantly see the effects of these parameters on the graphs of any function.

Above the list of functions are two buttons that provide more options. The **Add Item** button, which appears in the upper-left corner of the list, allows tables

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### Department editors

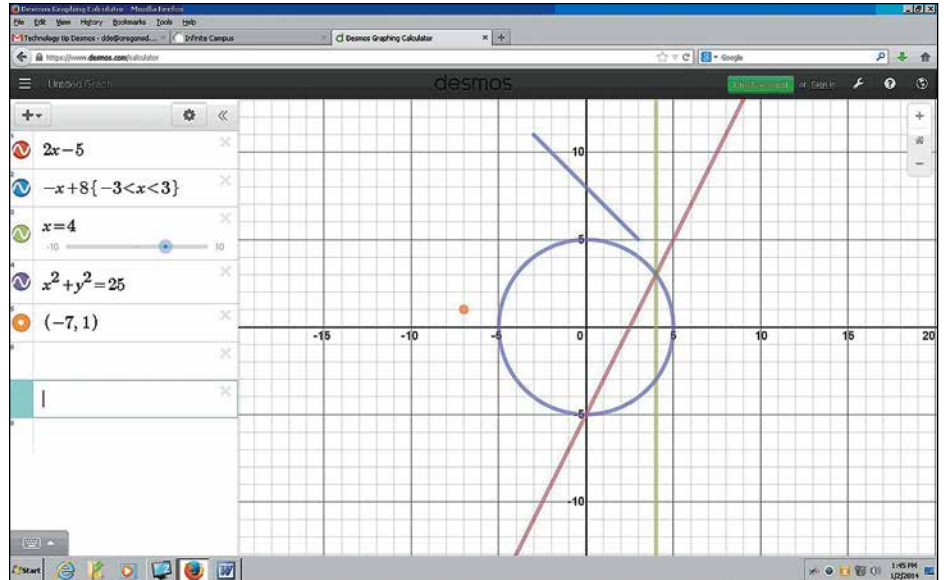
**Andrew Benzing**, [abenzin@wssd.org](mailto:abenzin@wssd.org), Strath Haven High School, Wallingford, PA; and  
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of values to be easily created. After selecting **Table**, users need to enter an expression to define the output. Rows and columns can be added with one click. As values are entered into the table, they are automatically graphed. The **Edit List** button, which appears as a cog in the upper-right corner of the list, allows users to duplicate equations, set boundaries on sliders, and convert equations to tables (see **fig. 3**).

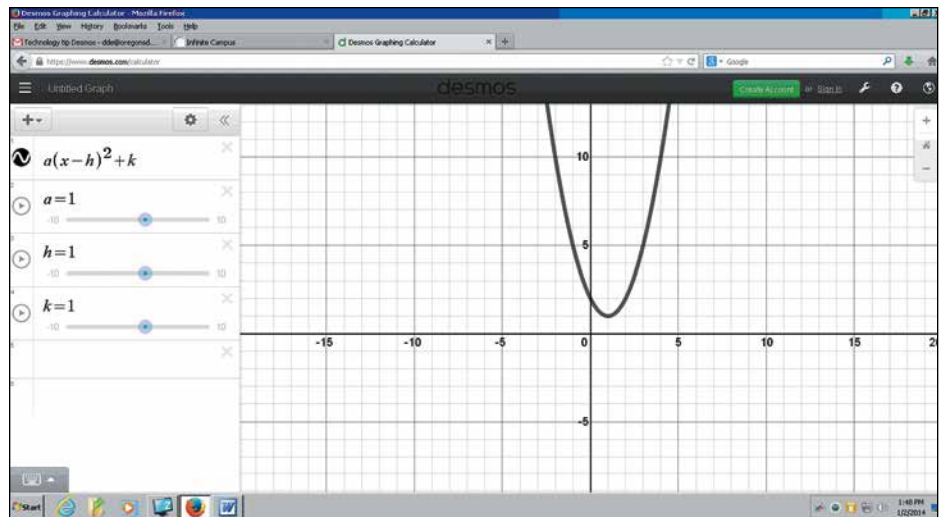
The **Window Settings** menu can be accessed by clicking on the wrench icon in the top-right corner of the window. This setting allows users to choose between Cartesian and polar grids, show or hide axes or grid lines, adjust the window of the graph, and select radian or degree scales for trigonometric function graphing (see **fig. 4**). In addition, the **Projector Mode** option makes the graph and axis lines thicker and all the expressions larger. This is a great option for using Desmos as part of a whole-group demonstration or with an interactive whiteboard.

Also available are a number of pre-made collections that teachers may use to demonstrate everything from the slope-intercept form of linear equations to exploring period and amplitude of trigonometric functions to changing parameters of conic sections to graphing derivatives of functions. These premade collections as well as any files that the user has saved may be accessed by clicking on the three horizontal segments in the top-left corner. The **Help** menu of Desmos is extremely user friendly, with options for users to learn more with interactive tours and a printable user guide. Tutorial videos on a variety of topics, such as restricting domain and range and creating sliders, are also available on the Desmos support page. Assistance can also be easily requested through Twitter, Facebook, or directly through the Desmos help page. A Desmos blog where project ideas are shared can be found at <http://blog.desmos.com/>.

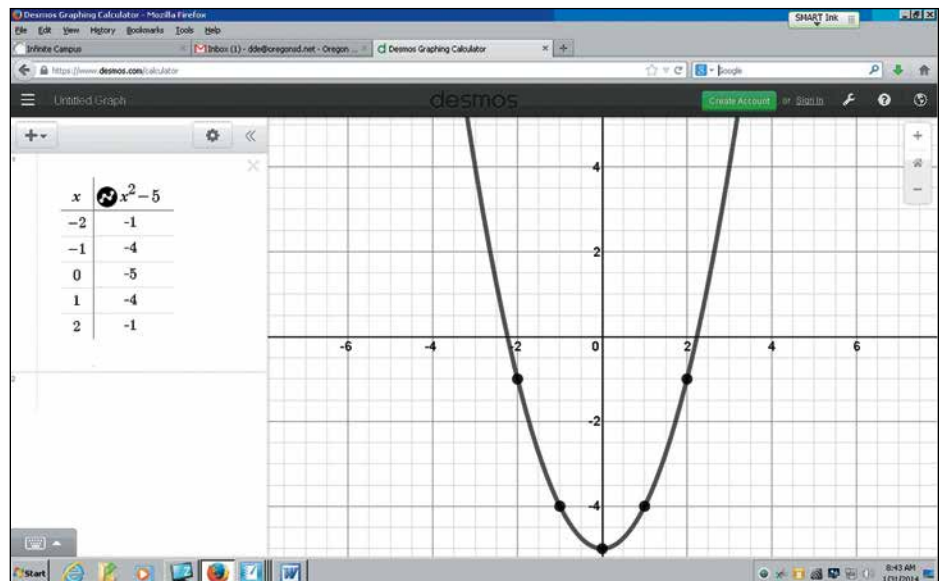
The Desmos team is responsive to the needs of its users and is constantly working to improve its product. I recently requested the capability to print both the graph and the list of equations, and within the month the Desmos programmers created the



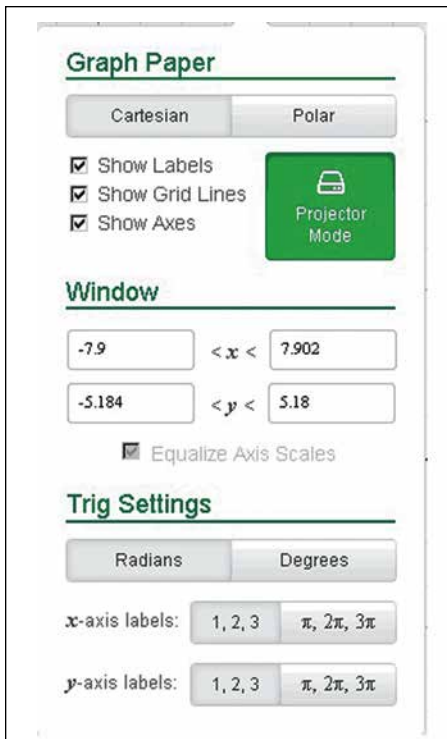
**Fig. 1** Sample input shows the graphing capabilities of Desmos.



**Fig. 2** Sliders for parameters are easily added in Desmos.



**Fig. 3** The **Table** function in Desmos represents values graphically as well.



**Fig. 4** The **Window Settings** menu provides display options.

capability to do so. New improvements include the ability to import an image, text, and folders. This useful addition allows teachers to import text and embed instructions for students within the document or pose questions to the class pertaining to a particular sketch. Being able to import an image allows teachers and students to explore

graphs in different ways—for example, attempting to fit a parabolic curve to an image of a water fountain (see **fig. 5**).

### DESIGN PROJECTS WITH DESMOS

In an Algebra 2 course, teachers could assign a creative design project at the conclusion of a unit on functions. In a precalculus course, teachers could assign it during the first week of school. Students are usually familiar with graphing a number of different functions from their previous class but need a reminder of the general shapes of these functions and transformations and how to apply restrictions on the domains or ranges of functions. Most students have never used Desmos before, so a brief introduction to go over the expectations of the project and demonstrate the basics of using Desmos is required at the onset of the project. A sample assignment available as a customizable worksheet at [www.nctm.org/mt](http://www.nctm.org/mt) includes project requirements (see the Design Project Requirements sidebar) as well as a list of basic functions and user notes for students.

A ten-minute introduction is all that students need before they begin exploring on their own. Once students are shown how to create a basic face using a circle for the head, part of a parabola for the mouth, points for eyes, and part of a sine curve for a mustache, they are

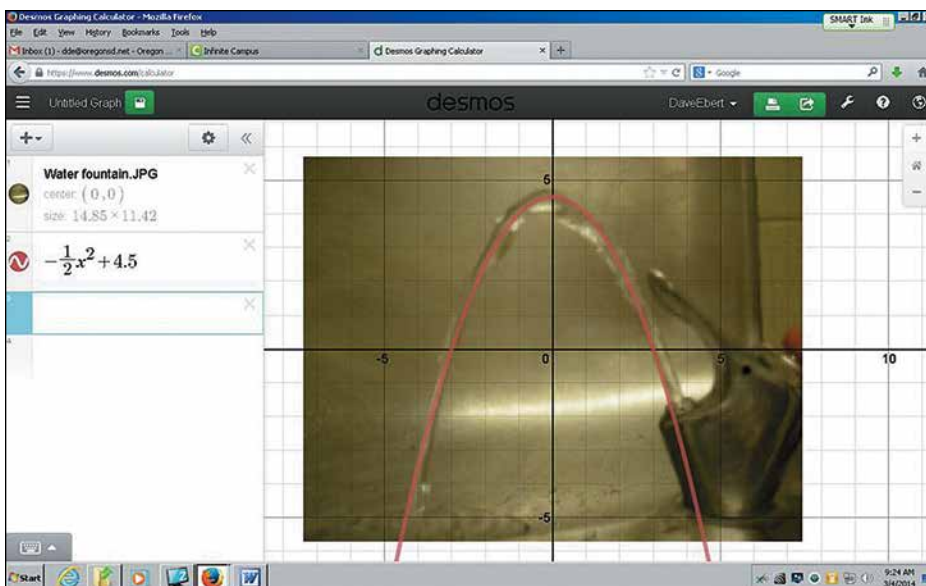
### DESIGN PROJECT REQUIREMENTS

1. Start with a rough sketch on paper before starting on the computer.
2. Every design must contain at least one sine curve.
3. Use at least seven different basic graphs from the class list (you may use more). Using other equations is also permitted, but these do not count toward the seven needed from the class list.
4. Use transformations for at least 90 percent of your equations.
5. Use restricted domains (piecewise functions) for at least 80 percent of your equations.
6. You must have a minimum of ten equations.
7. Use at least one inequality.
8. Creativity is a plus!

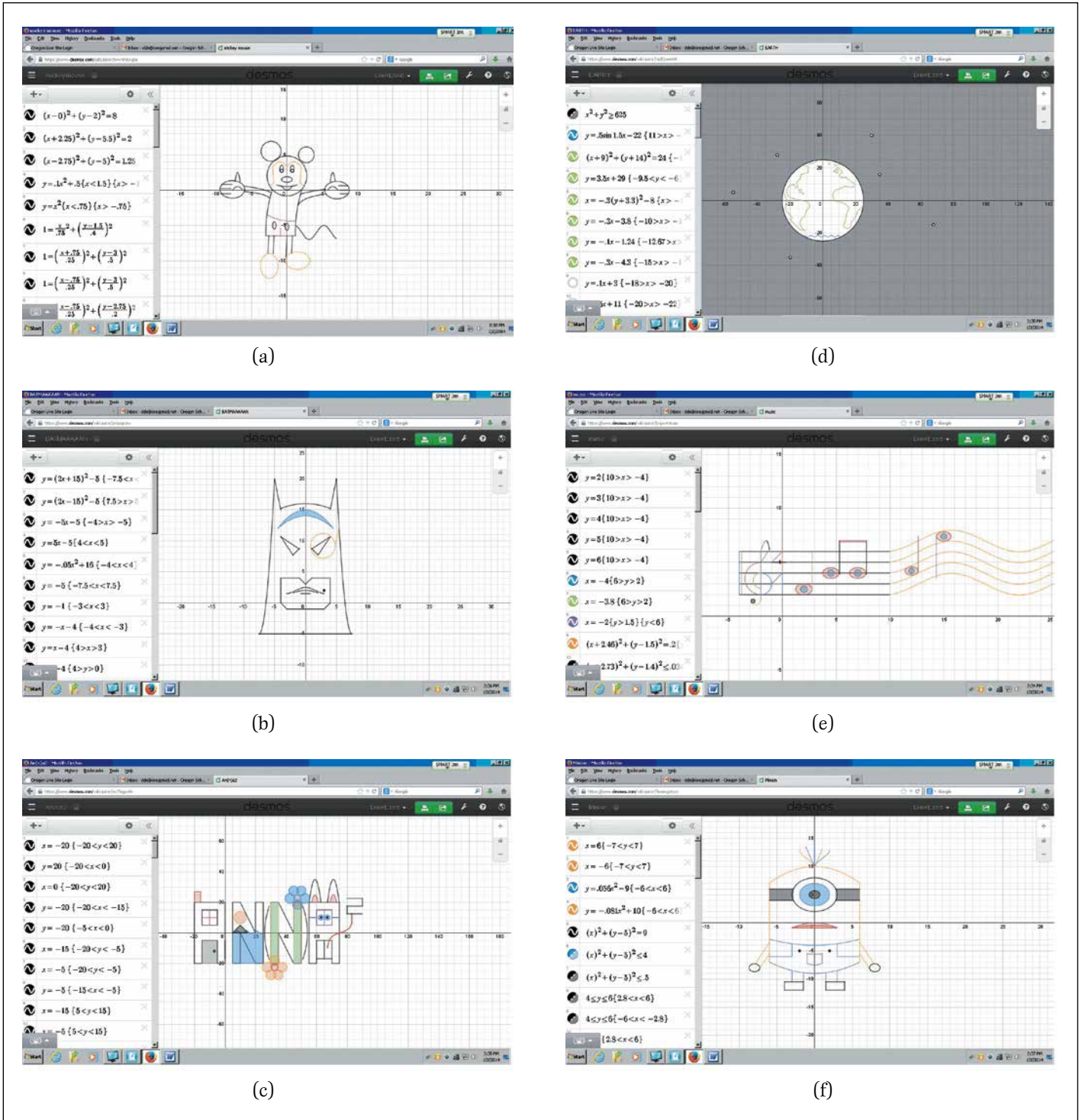
ready to go. Two to three class periods of forty-five minutes are sufficient for students to complete the entire project, but most are so fully engaged in their projects that they devote a significant amount of time outside class to perfecting their design.

When the students complete the project, Desmos allows them to email the project to their teacher. Final designs, along with the list of equations needed to create the design, may be printed and displayed. Designs may also be embedded in external websites. Many students go far above and beyond the requirements of the project and are extremely proud of their work. **Figure 6** shows a sample of students' designs.

Students review, learn, and reinforce graphing equations and inequalities using transformations, and graphing piecewise functions through a fun and challenging project. Many programs, apps, and calculators will allow students to explore graphs of equations. Although other types of software allow students to do everything mentioned in this article, Desmos is an easy-to-use, intuitive, powerful tool that should be explored by any mathematics teacher who teaches the graphing of equations.



**Fig. 5** Importing an image in Desmos creates opportunity for modeling and mathematical analysis.



**Fig. 6** Some of these student project designs are made up of more than one hundred equations.



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**Editor's note:**

With the most recent update, the Desmos team has included an app for the iPhone®—great news for teachers and students who have access to handheld devices running iOS but might not have laptops or iPads in class.



For an activity available to teachers as a Word document that can be copied and edited for classroom use, go to [www.nctm.org/mt](http://www.nctm.org/mt).