

Using Desmos to draw in mathematics

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Introduction

During their middle and early high school years, students generally finalise their attitude towards mathematics and their perception of themselves as students of mathematics, in terms of aptitude, motivation, interest, and competence (NCTM, 2000). Therefore, giving them varied opportunities to foster a positive and successful approach to the study of mathematics is critical, and can help them appreciate the relevance, usefulness, and creativity of the subject. Most teachers are looking for innovative ways to capture, foster, and encourage their students' interest in mathematics, whilst at the same time conveying the required content. Furthermore, various educational organisations extol the power and usefulness of technological tools in the mathematics classroom. For example, the *Common Core Standards* (CCSSI, 2010) state that mathematically proficient students “are able to use technology to explore and deepen their understanding of concepts” (p. 7). NCTM's *Principles to Actions* states that “an excellent mathematics program integrates the use of mathematical tools and technology as essential resources to help students learn and make sense of mathematical ideas, reason mathematically, and communicate their mathematical thinking” (2014, p. 78). *The Australian Curriculum: Mathematics* (ACARA, 2014) includes the use of graphing software to foster the critical and creative thinking processes, and the ability to generate solutions.

A tool that can be used to engage students innovatively in mathematics, and supports the intent of the *Common Core Standards* and *Australian Curriculum*, is Desmos (<https://www.desmos.com/>). Desmos is a free online graphing calculator that runs as a browser application, and also as a mobile app. Just like a hand-held graphing calculator, Desmos can graph equations and inequalities, as well as being able to complete a variety of other computational features such as lists, plots, regressions, graph restriction, and simultaneous graphing tasks. The most obvious advantage of Desmos is that the screen is as large as the screen of the device on which it runs and therefore much bigger than that of a graphing calculator. In addition, Desmos is much faster at graphing, thus providing immediate feedback to the students who can see the function change in real-time as they modify parameters.

Background to the project

For this class project, the students were asked to create a drawing with Desmos, using different functions and their transformations. At the school where I teach—an independent all-girls school in the suburbs of Washington DC—each student has a laptop and access to the school's internet to replicate this task. However, all that is necessary is that students have access to a desktop computer or mobile device. In the case described here, the project was

assigned towards the beginning of the school year in an Algebra 2 class (roughly equating to Year 10 mathematics in Australia), so students were required to use linear, quadratic and absolute value functions, and some transformations such as translations and reflections. (Refer to Figure 1 on page 35 for instructions.)

However, this is an activity that can be used with any class where graphing is involved—for example, I am planning to use it later in the school year in my Algebra 1 class (approximately Year 8 mathematics in Australia), with just a slight modification of the requirements, instead of having the students create a hand-drawn picture as in previous years. Depending on what content a particular maths class is studying, or for a more advanced class, the instructions may require the students to use more challenging functions such as polynomials, trigonometric or rational functions, and so on.

The project was introduced in class and students were allowed the entire one-hour lesson to explore the online calculator and start their drawing. This also enabled students to become familiar with the Desmos interface, assist one another when required, and commence using the tools. The Desmos website provides a quick and easy-to-follow user guide and a library of pictures and drawings that can be used as examples and can help jump-start some ideas.

Students found Desmos to be both a flexible and very user-friendly tool. They supported each other when necessary, and learned quickly to manipulate the various features of the program to generate the lines that they were looking for. The instant feedback they received from the program made it engaging and enjoyable to explore what happens to the graph of functions as the parameters vary; much less frustrating to input an equation that produced the curve they expected or desired. It was a lot of fun to see them get a deeper comprehension of transformations and hear their exclamations of understanding and appreciation of the various rules.

Class activity and discussion

During the one-hour mathematics lesson, students developed a good understanding of Desmos and how the online graphing calculator works, and the associated capabilities that could be used for their project. Students who managed their time wisely were also able to finish most of the required work in class, so that they only had to add the finishing touches to the project at home (Figure 2).

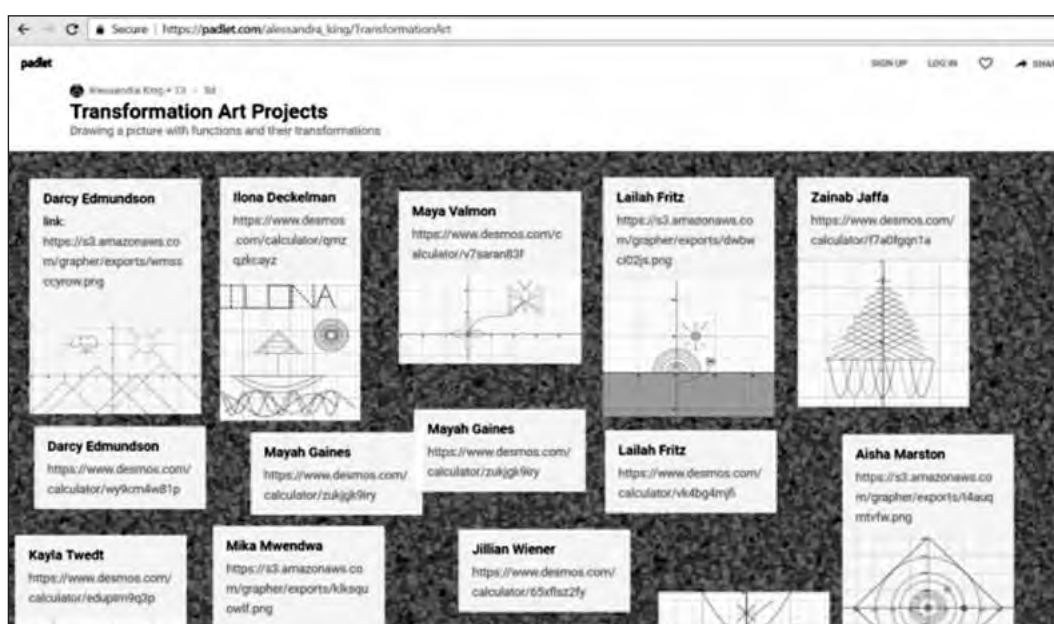


Figure 2. Completed student Desmos projects summarised using a Padlet interface.

Transformation art project

Class activity

Task

Your task is to create a picture using the different functions we have talked about this year. Your project must include the following:

1. At least 12 different functions (you may include vertical lines, as long as you remember these are not functions.)
2. At least 2 absolute value functions.
3. At least 2 linear functions.
4. At least 2 quadratic functions.
5. At least 2 horizontal or vertical translations.
6. At least 2 reflections (across the x - or y -axis).
7. At least 2 stretching/shrinking transformations along the x - or the y -axis.
8. An interesting and colorful graph.
9. An accurate and complete table listing each function, and its domain and range.
10. You can also use other functions, such as rational, square root, cubic root, and polynomial (cubic, quartic) functions.

Instructions

1. Create your graph art using the online graphing calculator, Desmos (<https://www.desmos.com/>). This calculator is very intuitive to learn and use. To support you in completing this task follow the link provided for a helpful Desmos user guide: http://s3.amazonaws.com/desmos/Desmos_User_Guide.pdf
2. Go to the Desmos website, and either:
 - a. “Start graphing”, or
 - b. Create a free Desmos account (recommended) by using your school Google account. This way you can also save your graph to your Google Drive.

Some hints

- To graph an equation, type the equation into the next line on the left (i.e., $y = 3x + 1$).
 - To restrict the domain, type your restricted domain in set notation after the function (for example: $y = 3x + 1 \{-2 < x < 4\}$).
3. Click along your graph in order to identify specific points on the function. By doing this you are identifying and choosing your domain and range for the graph. This will also assist you to fill in the function table, as you create your art instead of waiting until the end.
 4. Click on the Gear that says “Edit List” above your functions in order to change the color or line style of each equation.
 5. Make sure you **save** your graph!

Figure 1. Transformation art project—class activity.

Time spent on the activity in class also helped me to monitor the students' progress, and troubleshoot possible issues they could have encountered either with the Desmos calculator or the instructions. It also allowed the students to ask questions about the mathematical requirements, and to have a discussion with me and/or their classmates. These discussions fostered and deepened students' conceptual understanding of the various functions, the associated domains and ranges, the meaning of the needed constraints, and the significance and importance of the different transformations required for their picture.

Probably the biggest challenge for the students was to design a graph that was pleasing but at the same time not too complicated to draw with functions, so they spent some time at the beginning browsing the Desmos library of pictures to get some ideas. The full project was due 8–10 days later, a timeline the students approved of and were able to follow without difficulty.

Evaluation and assessment

This is a particularly valuable activity in terms of its ability to foster a strong conceptual understanding of functions and especially of transformations. The students get a better grasp of how the different transformations work—for example, what it means to translate a parabola up or down, left or right, or of how the negative sign (and its position) affect the direction of the graph of a function. It is particularly interesting to watch them explore stretching and shrinking a function by varying the coefficients and receive immediate feedback on their attempts. Varying the domain of the various functions—to allow only parts of them to show in the drawing—helps enormously to clarify a concept that is fairly abstract and not easy to relate to or to apply to real-life situations.

As for the formal assessment of this project, students were required to submit their drawings on Padlet, and also in hard copy format. [Note that details are provided at the end of this article about how to log on to the Padlet site created for this project activity].

Linking completed Desmos drawings make it easier for a teacher to check that students have followed directions, and it is possible to see the functions used in the drawings given they are summarised on the side panel of their picture. Students were provided with a marking rubric that was used to grade the project. The rubric was developed using Rubistar (<http://rubistar.4teachers.org/index.php>), and set-up as a generic tool, so that it could be adjusted easily to any specification and/or project.

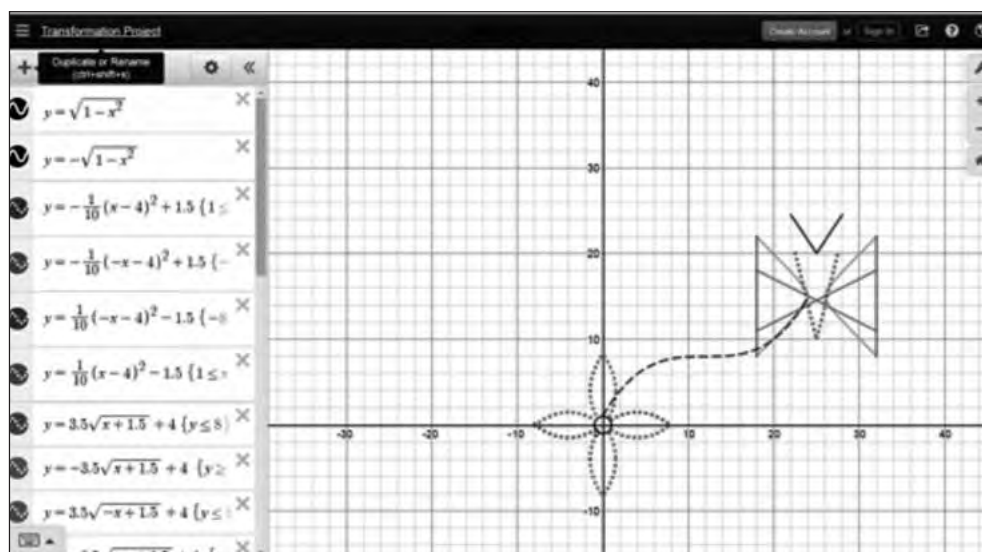


Figure 3. Sample student Desmos project [<https://www.desmos.com/calculator/v7saran83f>].

Conclusion

This project was successful in the classes where it was implemented (some of my colleagues used it too), and was valued by the students. Its emphasis on creativity, initiative, inquiry, exploration, and independent work—all features of enriching tasks—can captivate students' interest and it certainly encourages a deeper understanding of some mathematical concepts such as functions, domain and range, transformations, etc. that can be rather dry. Using mathematics for an artistic endeavor does not happen very often in mathematics classes and students appreciated having an opportunity to work on their own at their own pace, whilst still collaborating with their mates. The students' positive responses, constructive attitudes, and evidence of completing the activity are learning outcomes that led me to conclude that this is a valuable activity that provided a deeper conceptual understanding. Other areas of the student experience from completing this activity included higher student engagement in terms of discovery and exploration; promotion of higher-level thinking skills; and improvement in students' visualisation skills. Students also got to experience first-hand what can make mathematics more engaging and fun.

References

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- Council of Teachers of Mathematics (NCTM). (2014). *Principles to Actions: Ensuring Mathematical Success for all*. Reston, VA: National Council of Teachers of Mathematics. Retrieved 23 April 2017 from <http://www.nctm.org/standards/>
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Padlet logon

Padlet logon details for completed student work samples (Refer Figure 2)

URL: https://padlet.com/alessandra_king/TransformationArt

Password: Alg2TrigDA

Links to completed student Desmos projects:

<https://www.desmos.com/calculator/v7saran83f> (refer Figure 3 for sample interface)

<https://www.desmos.com/calculator/qmzqzkayz>

<https://www.desmos.com/calculator/65xflsz2fy>

<https://www.desmos.com/calculator/eduptm9q3p>

<https://www.desmos.com/calculator/klksquowlf>

<https://www.desmos.com/calculator/f7a0fgqn1a>

<https://www.desmos.com/calculator/vk4bg4mjfi>

<https://www.desmos.com/calculator/eduptm9q3p>