3D Printing from Math Equations

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Duration: Two hours

Introduction

This is a free resource for teachers and students and is part of the [Callysto](#) project, a federally-funded initiative to foster computational thinking and data literacy in Canadian Grade 5-12 classrooms.

3D printers are desktop devices that can create solid, three dimensional objects ranging in complexity from something like a small toy to a sophisticated piece of machinery with gears, levers, springs and more. These printers typically use a material such as a plastic filament or liquid resin which are extruded by a print head, laid down in layer on top of layer, in order to build up the solid printed object. Here is an image of a simple surface, printed in PLA plastic.
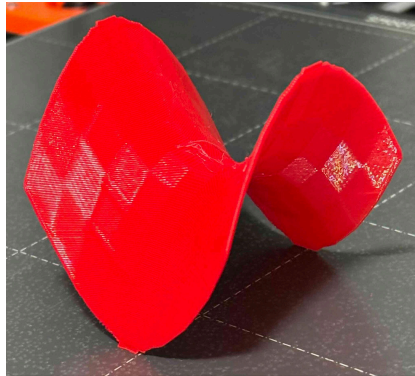
A saddle-shaped surface in 3D print

Many schools now provide access to 3D printers, either within the classroom or through online services. Students can utilize a library of pre-designed objects for 3D printing.

The primary objective of this lesson is to guide students in designing their own 3D models and preparing the files for printing on a 3D printer.

Throughout the lesson, we will illustrate how a 3D object can be defined by its surface, represented by a set of vertices and triangular faces. Using Python code, we'll demonstrate how to describe a surface mathematically, visualize it in a computer scene, and generate an STL file. The STL file is a standard format for 3D printing, viewable online, and convertible to a g-code file suitable for loading onto a 3D printer.

The notebook provides editable examples for students to create personalized 3D models. If a 3D printer is accessible, students can print their models. Jupyter notebooks serve as the primary framework, and free online tools can convert the outcomes into printable files.

Grade level and audience

Grades 9 - 12

Learning outcomes/curriculum connections

- This lesson connects CTF and CTS outcomes by blending digital technology, programming, and hands-on 3D printing and design. It provides students with a well-rounded learning experience, merging theory with practical skills to prepare them for the changing tech field.
- Grade 10-12 Mathematic curriculum
  - Relations and functions
  - Geometry
  - Measurements: length, area, volume

Required materials

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1. A charged computer.
2. Access to the internet.
3. An installed internet browser, preferably Google Chrome.
4. A Google or an Outlook email account.

Students should know how to log in to the Callysto Hub as well as run a notebook prior to interacting with it. Teachers, to get started with Callysto notebooks and running material on the Callysto Hub, see our Starter Kit.

To 3D print the results of this lesson plan, you will need:
- A 3D printer with supplies
- 3D slicer software such as Slic3r or PrusaSlicer

In-class activities

Activity 1 : Creating a 3D model of a pyramid, cube, and saddle surface
60 mins, plus time for the 3D printer

Link to notebook: 3D Printing.ipynb

In this activity, students will learn how a solid object can be represented as a surface enclosing the solid, and describe the surface as a collection of vertices and triangular faces. A pyramid is described in Python code, then converted to an STD file which can be viewed online and converted to g-code for a 3D printer. The next example is a cube, which also is described as a collection of triangles (two triangles for each square face of the cube) which then can be printed. Finally a saddle-shaped surface (a parabolic hyperboloid) is described in mathematical equation form, next displayed as a 3D plot on the screen, and finally converted to a collection of triangles that are stored in the STL file for printing.

Suggestions are given for creating other surfaces from mathematical formulas.

Activity 2 : Polar coordinates for printing a 3D sphere
60 mins, plus time for the 3D printer

Link to notebook: 3Dprinting-polar.ipynb

Students are introduced to polar coordinates in the xy-plane, with a radius r and angle theta to describe points on the plane. These are then used to describe circularly symmetric 3D models such as a sphere. We then create Python code to describe the sphere as a collection of vertices and triangular faces, then convert to an STL file that can be viewed on the screen and printed on a 3D printer. There are suggestions for equations for other surfaces to print using polar coordinates.

Reflections

- *What parts of this project do you think worked really well and why?*
- *Did you face any difficulties during the project, and how did you manage to solve them?*
- *If you had the chance to do the project again, what things would you want to change or make better, and what would you keep the same? Explain why you feel that way.*

- *Can you see any ways the things you learned in this project could be useful in your other schoolwork, lessons, or things you've experienced*

Next steps

For more information, you can check out our YouTube videos, online courses, or callysto.ca for learning modules, tutorials, lesson plans, exercises and events.

Contact

If you encounter any issues or have any suggestions, please get in touch with us at contact@callysto.ca or twitter.com/callysto_canada.