**Youth Explore Trades Skills Design and Drafting – 3D Modelling (Architectural CAD)**

# Prototyping Your Model Using 3D Printing and CNC Technology

## Description

In this activity, the teacher will discuss and demonstrate possible prototyping options using 3D printing and CNC technology.

## Lesson Objectives

The student will be able to:

* Know the file formats necessary for 3D printing and CNC
* Save a file into the appropriate file formats
* Understand 3D printing as an additive technology
* Understand CNC as a subtractive technology
* Send a file for 3D printing or CNC cutting
* Understand the function of G-Code and how it relates to the operation of a CNC

## Assumptions

The student will:

* Know how to login to a computer and open up the software
* Know how to save their work
* Know the skills learned in the following activities:
  + Exploring SketchUp Make
  + Creating a Simple Architectural Structure
  + Modelling Your Structure

## Terminology

**3D printing**: a rapid prototyping process that creates a physical object from a digital 3D model, typically by laying down many successive layers of material.

**Additive technology**: a technology that creates prototypes by adding material.

**CAM software**: specialized computer aided manufacturing software that controls machine tools and related machinery in the manufacturing of workpieces. In this activity, CAM software refers to software that controls a CNC router.

**CNC machining**: a process used in the manufacturing sector that involves the use of Computer Numerical Control machines.



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**CNC router**: a router that is controlled by a computer and used for rapid prototyping, typically by removing material with a cutting bit.

* 1. **ode**: a coding language that tells computer numeric machines how to make something.

**Subtractive technology**: a technology that creates prototypes by removing material.

## Estimated Time

1–5 hours (this will depend on what technology is available, and the complexity of the model being prototyped)

## Recommended Number of Students

20, based on *BC Technology Educators’ Best Practice Guide*

## Facilities

Computer lab installed with CAD and CAM software (SketchUp Make, AutoCAD, GibbsCAM, Mastercam, etc.), as well as a CNC router and/or 3D printer

## Tools

Projector with computer and speakers, Internet access, 3D printer, CNC router

## Materials

* + - Student Activity “Prototyping Your Model Using 3D Printing and CNC Technology”
    - Internet access
    - Material for 3D printer or CNC router

## Resources

Thingiverse [www.thingiverse.com](http://www.thingiverse.com/)

Extension Warehouse https://extensions.sketchup.com

## Teacher-led Activity

Use a computer with a projector and demonstrate the following:

* + - Introduction to rapid prototyping: 3D printing and CNC, additive and subtractive technologies
    - What .stl. and .dxf file extensions are
    - How to save your SketchUp model or CAD file as .stl or .dxf file extensions
    - Ways to 3D print your .stl file
    - Ways to CNC your .dxf file
    - The function of G-Code in CNC

## Student Activity

Students will 3D print their shed or CNC the floor plan of their shed, depending on availability of prototyping equipment.

## Assessment

Students will self-assess their prototype, including their new understanding of subtractive and additive technology, as well as the use of G-Code.

### The goal of self-assessment:

Can the student recognize personal strengths and weaknesses over time and become a stronger, more independent learner?

### Some self-assessment critical questions for students:

* + - What new information have I learned? How will I act on this information—accept, reject, or modify?
    - What new knowledge and understanding have I gained from this activity?
    - What is the new systematic process I have learned, and have I completely investigated this topic, or is there room for further investigation?
    - What direction do I want to take for future investigation?
    - How did my prototype turn out? Using my new understanding of prototyping, how could I improve my prototype? Does it involve a change in the modelling process, tooling, etc.?

### Some self-assessment strategies for students:

* + - Use interaction with and feedback from teachers and peers to guide own learning process.
    - Monitor the gathered information and new knowledge, and assess for gaps or weaknesses.
    - Seek appropriate help when it is needed.

# Introduction to rapid prototyping: 3D printing and CNC, additive and subtractive technologies

Rapid prototyping technologies are rampant in industry. There are two main types of rapid prototyping technologies: additive and subtractive technologies.

*Additive technologies*, such as a 3D printer, are those that add or build material to create a prototype. There are many different types of 3D printers, but those most commonly found in an educational environment use Fused Deposition Modelling (FDM). An FDM printer is like a hot glue gun operated by a robot that only speaks in x, y, and z coordinates. A model is created

by adding layer upon layer of plastic until the model is complete. Essentially, the build material melts, hardens, and fuses layer upon layer. Because you start with a fresh slate and add material to create your model, this is an additive technology. The most common materials to print in an educational setting are ABS and PLA plastics.

*Subtractive technologies*, such as a Computer Numerical Control (CNC) machine, are those that remove material to create a prototype. The CNC machine most commonly found in an educational setting is the CNC router. The CNC router, more or less, is controlled by a robot that only speaks in x, y, and z coordinates. It creates a model by removing layer after layer of modelling material until the model is complete. Because you start with a piece of modelling material that you cut away to create your model, this is a subtractive technology. In an educational setting the CNC router most commonly cuts wood, plastic, and Styrofoam.

### What are .stl and .dxf file extensions?

In order to use a 3D printer or CNC router to create your model, you need to save your file with a specific file extension. Typically, 3D printing software requires .stl files and CNC router software requires .dxf files.

**An .stl file** takes a 3D object and slices it into many layers, then translates that information into x, y, and z coordinates. This type of file can be imported into brand-specific 3D printing software, where the user can determine how big, how many, and what quality of print they’d

like their model. Once these factors are determined, the 3D printing software sends a machine- specific file to the printer and you can begin your print.

**A .dxf file** can be 2D or 3D; however, a CNC router typically found in an educational setting

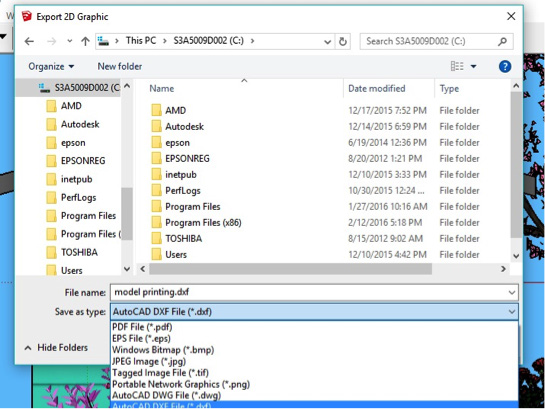
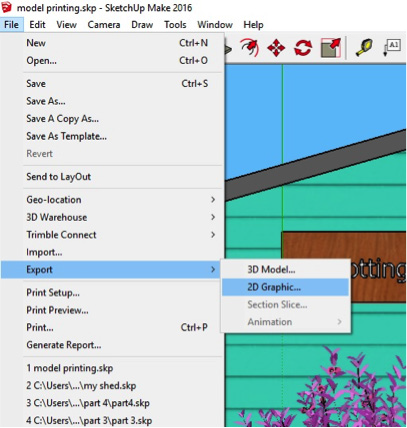
will not be able to create a model of your shed with windows and roof. The CNC router typically found in schools has three axes. However, you would require a five-axis machine in order to cut out your shed with windows and a roof. A three-axis CNC router could easily create a model of your floor plan with walls, as long as your walls are 90 degrees to the CNC table. This machine cannot come in from the side and cut out windows, doors, or overhang.

So, you can use your SketchUp shed file (as long as you return your file to walls only) or your CAD floor plan file (walls only, no light fixtures or windows, etc.). You can save either file as a

2D .dxf, then import it into a CAM software like GibbsCAM or Mastercam, where you can create toolpaths for the CNC to follow to cut out your floor plan. At this point, you could save your machine-specific file, and then run the code on your CNC router.

### How to save your SketchUp model or CAD file as those file extensions

In **SketchUp** and CAD, it is easy to save your file as a .dxf. Remember, you only want to save the file that has your walls, but no other extraneous details. You simply go to File, Export. When you save, select the .dxf file type (Figure 1). The steps are almost identical for SketchUp and AutoCAD, except SketchUp asks you to specify 2D or 3D before it allows you to save as .dxf.



**Figure 1**

In SketchUp, you cannot easily save your file as an .stl. You first must download an .stl converter, located in the extension warehouse:

https://extensions.sketchup.com/en/content/sketchup-stl



**Figure 2**

Once you install the .stl converter, you will be able to save your shed as an stl as shown in Figure 2: File, Export STL. If you have added trees or other items, you may want to remove them so only your shed remains in your SketchUp file before you do the file conversion.

### Ways to 3D print your .stl file or CNC cut your .dxf file

If your school does not have a 3D printer or a CNC router and you would like to 3D print or model your shed, there are many options. Perhaps another school in your district or a nearby college/university or library owns a 3D printer or a CNC router and would print or cut the file for you. Ask your instructor for suggestions. If not, there are online companies that will 3D print or cut and ship your model to you.

### The function of G-Code in CNC

G-code is a language used by people to tell CNC machines how to make something. The “how” is defined by instructions on where to move, how fast to move, and what path to move. The CAM software, like Mastercam and GibbsCAM, creates the G-Code from your .dxf file. In the code, the common parameters are defined with the letter G, hence G-Code.

Examples of G-Code:

**G0 X1 Y1** → G0 is the axis position with rapid movement; therefore, the CNC cutter moves quickly to (1,1).

**G0 Z-0.1** → G0 is the axis position with rapid movement; therefore the CNC cutter moves down quickly to a distance of 0.1 above your material.

**G1 Z-4 F10** → G1 is a controlled feed movement, meaning the CNC cutter moves down at a feed speed of 10 and cuts into your material a distance of 4.

**G1 X2 Y4** → G1 is a controlled feed movement, meaning the CNC cutter continues to cut at a feed speed of 10, and cuts over to location (2,4).

G-Code also uses other letters, like M and T; however, G is the most prominent letter in the code. This coding language is basic yet tedious, and although it is possible to write the code and send it to the CNC, it is highly uncommon. Because we have software that creates a more accurate and machine-specific G-Code, people no longer feel the need to write G-Code.

However, it is important to have an understanding of G-Code. If a machine makes a mistake, for example, we can scroll through the code, determine where the mistake was made, and modify the code to reflect the correction.