

3D PRINTING 101: AN INTRO

This facilitator guide is a companion to the step-by-step directions for **3D Printing 101**. It is intended to guide the facilitator through setting up, introducing some basic concepts of 3D design, guiding participants through the project, and debriefing the experience at the end. This is the first lesson in The Additive Project's 3D curriculum. As such, it can be offered as a stand alone immersion in 3D printing or immediately preceding **The Keychain Project** lesson also available on TheAdditiveProject.org.



3D Printing 101 familiarizes participants with working in 3D space and introduces some online resources and printer software. Some fundamental tools and techniques necessary for creating objects are also introduced.

LEARNING OBJECTIVES

- Understand How 3D Printing Works
- Learn Basic Components of a 3D Model
- Learn the File Types Required for 3D Printing
- Learn How to Navigate Thingiverse + Download Objects
- Learn How Import + Prep Models in MakerWare
- Learn How to Prep + Print with a MakerBot Machine

PROJECT OVERVIEW

- Introduction
 - Overview of Prototyping and Uses of Customization (Optional)
 - Skills Lesson
 - Project Work Round
 - OR Tool Lessons
 - Guided Project Work Round
 - Debrief + Class Summary
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SKILLS OVERVIEW

This project was developed for use with MakerWare software and MakerBot printers. The following skills will be learned through the introduction and/or repeated use of the relevant tools, available for view in the Tutorials included in the step-by-step.

PROGRAM BASICS

OPENING MAKERWARE

Open and explore MakerWare

OPENING AN STL FILE

Accessing a saved STL file for print

ADDING FILES

Import files to the print space

EXPORTING FILES

Export files for Print Preview + Print

VIEWING + MOVING

CAMERA ROTATION TOOL

Making adjustments in the camera view.

ZOOM

View objects close up or at a distance.

MOVING OBJECTS

Changing the placement of objects on the printer bed.

ROTATING OBJECTS

Adjusting the orientation of objects on the print bed

SCALING OBJECTS

Adjusting the size of objects with regard to print time

PREP + MATERIALS

CLASSROOM RESOURCES

COMPUTER ACCESS:

Each participant should have his or her own computer for the duration of the project.

PRESENTATION + LECTURING:

Ideally, you should be able to play the Tutorials videos and walk the class through each Module by demonstration on a projector that all participants can see.

SOFTWARE REQUIREMENTS:

This project requires each computer to have MakerWare installed and available.

ACCESS REQUIREMENT:

This projects requires each student to have the ability to access the internet and download files. This can be done via the internet from The Additive Project site if access is available. Alternatively, you may download the file and preload it onto computers where the participants will have access.

PRINTING REQUIREMENT:

Currently, this project outlines the process for printing using the MakerBot Printer.

TIME

The lesson is designed to take 30-45m, depending on:

- The inclusion of the introduction
- Time spent on going over skills training
- Time spent debriefing

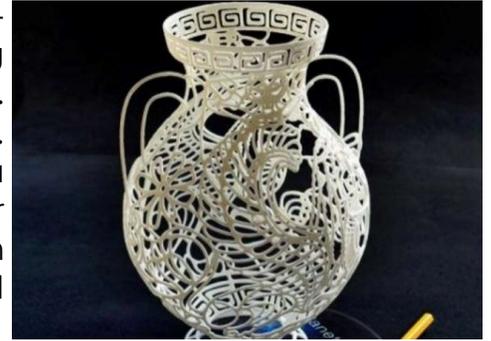
PRINT TIME

The objects in the Additive Collection on Thingiverse have been tested to create a viable object with possible print times of 20m or less (after scaling). This can be done at the end of the lesson or during another class period. The size and duration of the print is flexible and based on your access to printers.

3D PRINTING: AN INTRO

WHAT EXACTLY IS 3D PRINTING, ANYWAY?

3D printing, also known as additive manufacturing, is a process by which a three dimensional object is created using material which is laid out and fused in sequential layers. Think of an inkjet printer moving line by line down a page. Then think of a glue gun squeezing a line of glue into a shape on a table top and then retracing that shape over and over again until the layers begin to take the form of an object like a bowl. Mesh the two concepts, and you should have the idea.



There are several methods for printing in three dimensions. In the most common home, school and office applications, 3D printing is made possible by creating digital 3D models to very precise measurements with computer aided design (CAD) software or a 3D scanner. The models are then processed by "slicing" software, which maps out the series of layers, or slices, to be laid down to actually build the object. Most 3D printers available to the general public are simply industrial robots that follow these maps and squeeze out, or extrude, layers of material, fusing them along the way until objects have been created.

Most 3D printers you come across will use plastic polymers to create objects. The layers are fused together by the heat at which the material is extruded. One of the most common uses for these plastic objects is to develop and refine prototypes for manufacturing, though utilitarian objects such as prosthetic hands, patient-specific medical implants, custom eye-glasses and small mechanical components are also being made.

3D printers do not only work with plastics. The technology includes metals, glass and even biological materials. Industry has rapidly embraced 3D printing in metal as the process has been refined and newer, cheaper machines have made it possible to print parts in days which used to take months. There are also many types of industrial objects which were essentially impossible to properly manufacture before 3D printing. Scientists are even now exploring the possibilities for using the technology in space to print everything from replacement parts to habitable buildings.



SUGGESTED PROCESS

INTRODUCTION MODULE: OVERVIEW OF 3D PRINTING (OPTIONAL)

Show the “Overview of the Variety of 3D Printing” slidshare to show examples of exciting 3D printed objects. Play the introductory video of the 3D printing process. Pass around a printed object and present the associated talking points.

PROJECT FACILITATION

Direct participants to the project website. Introduce or review the project page components they can use as reference, showing them the step-by-step instructions, the location of the Required Files (refer them to their desktops if previously installed), and point out the Tool Tips + Tutorials section.

OPTION 1: With groups that do well independently, you may choose to begin the session by giving an overview of the learning objectives, as well as the tools needed to complete the project. Additionally, you might identify the goals, play the Tutorials videos, and let participants follow the step-by-step on the site.

OPTION 2: Alternatively, you may also break the session up into smaller segments or Modules, which each include several steps involving particular skills and allow for break points to check in with participants and teach the following Module’s new skills before progressing. Play Tool Tips videos and allow participants to follow the steps on the Additive site, play Tutorials videos, or demonstrate the steps to the class using projection.

MODULE 1: THINGIVERSE + OPEN SOURCE FILE SHARING

Step 1. Introduction to Thingiverse; the concept of open source object files; the breadth + scope of available files and their features.

MODULE 2: IMPORTING + MANIPULATING FILES; EXPORTING TO PRINT

Steps 2-7. Importing files; manipulating objects in the print space; scaling; exporting to print. Ensure all participants have completed this step before proceeding.

MODULE 3: PRINTING

Steps 8-11. Familiarization with the printer; STL cards; printer safety.

MODULE 4: DEBRIEF

Discussion questions.

FACILITATOR STEP-BY-STEP

INTRODUCTION MODULE (OPTIONAL)

GOAL

Gain a basic understanding of the possibilities of 3D printing; become familiar with the functionality, applications and mechanics of desktop plastic 3D printing.

MEDIA

Show the [Slideshare](#) for Overview of the Variety of 3D printing possibilities.

TALKING POINTS

- Today we are going to begin exploring 3D printing. We will be learning about how 3D printers work, exploring the file sharing site Thingiverse, working with printer software and printing a simple object. You will be able to reference step-by-step instructions, tutorial videos, and Tool Tips on The Additive Project website.
- Slide Show Talking Points by Slide:
 - ⇒ Slide 1: 3d Printing allows you to make simple things incredibly ornate such as this vase and then replicate it over and over again.
 - ⇒ Slide 2: To reinvent the way we think about things such as fashion as seen in this incredible 3d printed necklace
 - ⇒ Slide 3: The possibilities to reinvent don't have to be super complicated or large to be impressive such as these incredibly creative fake nails
 - ⇒ Slide 4: 3d printing can translate technology into beautiful functional objects such as this print of sound waves that can be played like a record using a laser.
 - ⇒ Slide 5: But even the simplest ideas can be amazing as seen in these customizable music boxes where customizing the placement of the pegs writes your own song
 - ⇒ Slide 6: You can recreate the world around you in incredible detail
 - ⇒ Slide 7: Or make your fantasy worlds come to life
 - ⇒ Slide 8: It helps reinvent amazing processes such as it's use in Paranorman to create 100's of unique faces for stop motion animation at a level of detail rarely seen
 - ⇒ Slide 9: But even a simple animation rendered using 3d has an amazing beauty to it and attracted millions of views
 - ⇒ Slide 10: 3d printing can allow you to create simple products like this object that turns sticks into a whisk
 - ⇒ Slide 11: Or unique products like this ice stool modification
 - ⇒ Slide 12: You can create beautiful mechanical objects
 - ⇒ Slide 13: Or reinvent industry in ways never before possible
 - ⇒ Slide 14: You can reinvent the ways we think about medicine and solutions that help people
 - ⇒ Slide 15: There are avenues to get exposure for your creative ideas in the art world
 - ⇒ Slide 16: Or ways to monetize them through the commercial world
 - ⇒ Slide 17: Your ability to share your ideas and work become easier and more mainstream by the day

MEDIA

Play the Tutorial: *Intro - Math Art 3D Print Timelapse*

FACILITATOR STEP-BY-STEP

TALKING POINTS

- In the video you can see the the object being created one layer at a time as the print bed lowers down away from the print nozzles.
- As the video progresses you can see material at the base of the object being removed. What you are seeing being removed is the support material that the printer needs to create to hold up the object when it is hanging over empty space
- The final object is an intricate sculpture that would be very difficult to sculpt and create a mold for that you can see was easily created using 3D printing.

MEDIA

Pass around a few printed objects and allow the participants to come up and view the printer. Optionally have the printer start to print an object.

TALKING POINTS

- 3D printing, also known as additive manufacturing, is a process by which a three dimensional object is created using material which is laid out and fused in sequential layers. Think of an inkjet printer moving line by line down a page. Then think of a glue gun squeezing a line of glue into a shape on a table top and then retracing that shape over and over again until the layers begin to take the form of an object like a bowl. Mesh the two concepts, and you should have the idea.
- Looking closely at the object, you should be able to identify the layers created by the 3D printer. Once an object is designed in 3D space, the printer creates coordinates for the surface area and then lays down layers of filament to build the object.
- To create large solid spaces, the printer is usually set to create a honeycomb pattern of material to serve as infill.
- As you can see on the object, the printer first lays down a thin, flat layer of material to print on. This is called the Raft.
- For parts of the object that are suspended in space, the printer first creates thin supports which are later cut away, or dissolved if using the appropriate filament.

MODULE 1: THINGIVERSE + OPEN SOURCE FILE SHARING

GOAL

Navigate Thingiverse and Download a File

MEDIA

- Play the Tutorial: *Open Browser + Navigate to Thingiverse*
- **OR** Demonstrate opening Thingiverse and navigating through collections

FACILITATOR STEP-BY-STEP

TALKING POINTS

- Navigate to the website Thingiverse on your browser. The Thingiverse site is dedicated to sharing user-created open source design files, many of which are designed to be made on 3D printers, laser cutters, milling machines and other technologies.
- The open source movement allows users to share and modify found and created content in just about any form.
- Thingiverse, which is run by the 3D printing company MakerBot, is a massive repository of printable objects which you can browse through the Explore tab at the top of the screen. Here you are able to choose from a menu that includes Things, Customizable Things, Collections, etc. A quick glance at the Things sections offers a sense of the range of 3D models that are available to print or customize.
- 3D models are simply the mathematical representations of all three dimensions of an object's surface which are generated by specialized programs.
- When exported to a 3D printer's software with its various practical settings, the printer uses the mathematical coordinates of each point on the surface to determine where and how much material to place in a series of layers and filler. In this way, a 3D model can be printed as an object in the real world.

MEDIA

- Play the Tutorial: *Locate + Access The Additive Project Files*
- **OR** Demonstrate navigating to the Thingiverse Additive Project Page, selecting and downloading a file.

TALKING POINTS

- First, some things to be aware of whenever you navigate through Thingiverse. Since these are open source files, the amount of instruction and testing can vary greatly.
- Open the file *Erebor Key* and look at the horizontal menu below the picture. You can see that it comes with background info and instructions, and that it has been successfully printed by a number of users among other things.
- Some files include a MakerBot verification, which simply indicates that the company has created and tested the file on its machines with success.
- User prints demonstrate that others have successfully printed and the instructions provide a how-to of printing, all of which are useful for beginners.
- Some Thingiverse projects are still in development, while others are complete and tested, and include all the necessary files to export directly to a printer.
- 3D printers use a file format called STL (for STereoLithography), which maps out the object's surfaces. These files can be imported and modified by a printer's software to actually print the object. If you intend to print an object, ensure you have the STL file.

FACILITATOR STEP-BY-STEP

- Once you have investigated the page's properties, download the *Erebor Key* STL file and save it in a convenient place on your computer.

MODULE 3: IMPORTING + MANIPULATING FILES; EXPORTING TO PRINT

GOAL

Working with a File in MakerWare + Preparing it for Print

MEDIA

- Play the Tutorial: *Place the Object in the Printspace*
- **OR** Demonstrate using the Text Tool to create text on the grid plane

TALKING POINTS

- Open MakerWare, select Add File and navigate to the saved STL file of the object you chose from Thingiverse. The object will appear in the MakerWare print space.
- Once the file is in the print space, accept the prompt to lay the object on the platform.
- If the object is in mid air in the print space, the printer will print on the exact coordinates, but will construct physical supports to get it there, increasing the print time and amount of material used.
- MakerWare attempts to give you an accurate representation of how the object will actually be placed and printed in the printer. The dark grey plane represents the print bed and the outlines of the box represent the limits of the printing space.
- In the Settings tab, you can see that Raft is checked. The raft is a flat piece of filament laid down as a base by the printer to print on. In settings, you can also check Supports, which will show you all supports. With these two selected, you have an accurate picture of exactly what will be printed.
- Think about the best way to orient the object for print, with fewer supports being preferable.
- *Reference the demonstration object to show how different orientations would require more or less support material.*

MEDIA

- Play the Tutorials: *Camera Manipulation; Moving; Rotating*
- **OR** Demonstrate the different views, moving and rotating.

TALKING POINTS

- MakerWare allows you to move and manipulate the object in the print space.
- Find and double click the View icon over to the left side of the screen. With this selected, you can drag the object along the print bed for a different placement to open a sub

FACILITATOR STEP-BY-STEP

menu that has options for some of the cardinal views.

- The Home view icon in the top left gives you the default view, which is useful if you ever get lost.
- Beside Home, there are also Zoom buttons.
- With View still selected and the sub menu closed, you can left click and hold your mouse to manually change the view.
- You can also zoom in and out with your mouse roller.
- By selecting the Move icon, you can select and drag the object on the print bed with your mouse.
- A second click will bring you to the sub menu in which you can move the object on all three axes by exact measurements, ensure the object is on the bed, and center the object.
- Similarly, the Turn icon and sub menu allow you to change the object's orientation on the print bed manually or by typing into the axis fields.

MEDIA

- Play the Tutorial: *Printing Time*
- **OR** Demonstrate exporting and scaling

TALKING POINTS

- To make final adjustments before printing, select the Export tab in the top menu. A pop up will appear showing the file being prepared for print. When this is complete, the file is ready for export. The window will expand to include a Print Preview option and will indicate the estimated time to print and amount of filament used.
- For our purposes, a 20 minute print time is ideal.
- If the print time of your object is longer than 20 minutes or so, cancel out of Export and return to Scale.
- Based on the print time the object had at the current size, fill in a percentage that might correspond to 20 minute print time. E.g. if the original print time was 1.5 hours as in the Tutorial, try a scale of 20% or lower for the object.
- Keep in mind that every time you scale the object, you create a new 100%. If you scaled it down to 20%, as in the Tutorial, and that is too small, you use the new size to base the percentage on (250% worked in our case). Alternatively, you can start from the original size by first selecting Reset Scale.

MODULE 4: PRINTING

GOAL

Successfully print an object

FACILITATOR STEP-BY-STEP

MEDIA

- Play the Tutorial: *Printer Preparation*
- **OR** Demonstrate Exporting to the Printer or SD Card

TALKING POINTS

- Once you have the right print time, click Export Now and save the file.
- Power on the printer to preheat it. The printer must be hot for the filament to adhere to itself during printing. Keep the door closed as much as possible and always when printing.
- Preheating before you are ready to print allows you to save time when you are ready. Preheating can take up to 10 mins so if you do this while you are working on or preparing your model you will save time. If you do not preheat your printer before you print it will begin this process when you select the model to print.
- On the MakerBot Replicator 2X, scroll down the initial menu and select Preheat. On the next screen, you will see the option Start Preheat! Check that the Right + Left Tools and the Platform are all ON. Select Start Preheat! You will see that the Platform heats up to 110 degrees while the L + R Extruders wait. When the Platform is close to the right temperature, the extruders will begin to heat.
- Depending on the generation, MakerBot printers have a variety of control panel configurations. Where there's a D pad (directional control pad), the M button in the center will select whatever option is highlighted, left goes back through the options, while up and down scroll through the menus. Others, such as the Replicator, have an LCD display and a dial.
- The SD card allows you to easily and securely move the large 3D print file to the printer. The card has a notched corner on the end that is inserted into the computer and printer. Make sure you insert it with the arrow pointing in and facing you.
- Once it is inserted, Select Build From SD, scroll down to select the file you wish to print.

MEDIA

- Play the Tutorials: *When Things Go Wrong; Cancelling a Print*
- **OR** Demonstrate canceling a print

TALKING POINTS

- It is always important to monitor your machine while it is printing in order to catch any errors or malfunctions as quickly as possible. Should a problem occur, remember that the printer plate is very hot, so do not touch it until it has cooled down. In general, keep the door closed until the printer is fully cooled. Opening the door while printing will disrupt the job and drop the temperature, possibly leading to print failure.

FACILITATOR STEP-BY-STEP

- MakerBots are great machines, but sometimes things go wrong. More common malfunctions include obstructed or non-working extruders, where the filament is not flowing to the print properly or at all; the printer head sticking on a piece of extruded filament and dragging the piece; extruders getting off alignment. Patience is key when printing objects.
- Should anything go wrong with your print job, hit the left arrow key to bring up a menu of print options and choose cancel print.

MODULE 5: DEBRIEF (OPTIONAL)

GOAL

Make sure any work in progress is saved. Discuss and answer any questions related to the project.

TALKING POINTS

- What do you think about 3d printing?
- What is the most interesting thing you learned today?
- What was the most challenging part of this project?