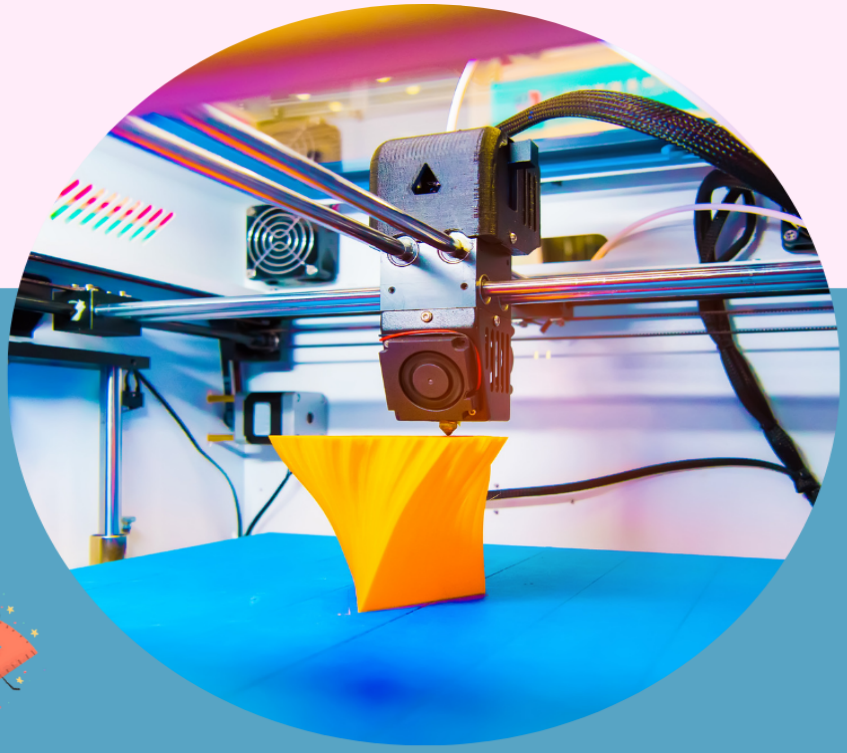
recreaMATHS

3D - Printing Laboratory Manual

Practical Tips & Safety rules for a successful 3D - Print



Introduction

With the implementation of 3D printing going mainstream in many school boards, departments are now being asked for their input and recommendations when implementing this technology. School boards are often in uncharted waters as they develop their recommendations and/or share **health and safety guidelines** for the use of 3D printers in their schools and classrooms.

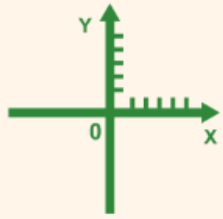
Figure 1 / Teacher and students with their 3D printed parts

Following the **"recreaMATHS 3D Printing Module",** this **"Non-formal Laboratory Manual"** provides information on technical aspects of the 3D Printing process (temperatures, set-up, etc.) whilst providing a clear understanding of the functionalities of a 3D Printer.

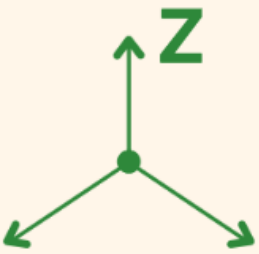
Parts of a 3D Printer

If you are a beginner looking to start 3D printing, your first 3D printer will most likely be an FDM printer. FDM is the most known 3D Printing process. It is a bottom-up technique based on melting of the filament and depositing it on a table layer-by-layer according to the sliced model.

The easiest way to understand how FDM works is to first learn the parts of an FDM 3D printer. Before we talk about specific parts, though, it's worth mentioning that 3D printers use **three axes: X, Y, and Z.**



- **x axis is responsible for the left / right movements**
- **y axis is responsible for the forward / backward movements**



- **z axis is responsible for the up / down movements**

The X- and Y-axes are responsible for left and right, forward, and backward horizontal movements respectively, while the Z-axis handles vertical movement.

Let's take a look at the **main components of a 3D Printer**:

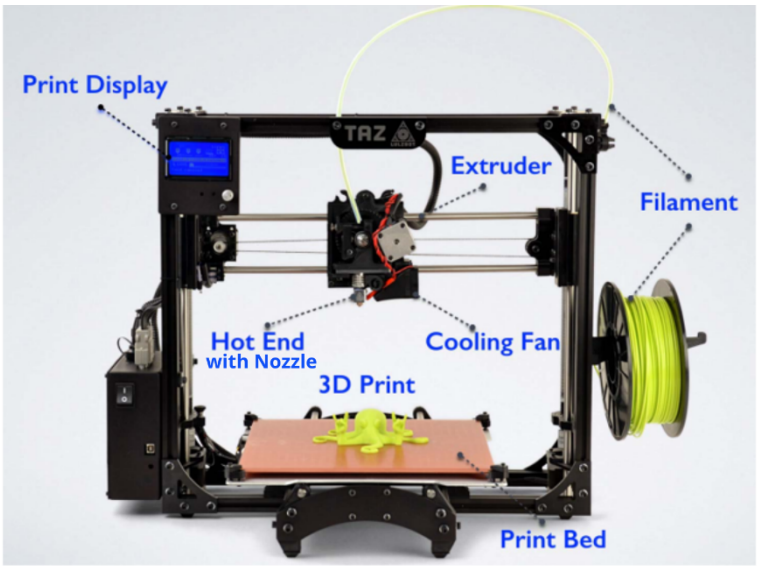


Figure 2 / Main components of an FDM 3D Printer

Source: http://my3dconcepts.com/explore/main-components-of-desktop-3d-printers/

The hot end is **one of the most essential components of a 3D printer, as it heats the filament and pushes it through the attached nozzle**.

To fully understand what it's like printing an item with a 3D machine, let's look at the main 3D-Printer parts:

3D Printing Filament

3D printing filament is a thermoplastic, or polymer, that melts when heated and is extruded through a nozzle layer by layer to create a three-dimensional object.

Polylactic Acid, commonly known as PLA, is one of the most popular materials used in desktop 3D printing. **It is the default filament of choice for most extrusion-based 3D printers because it can be printed at a low temperature and does not require a heated bed.** PLA is a great first material to use as you are learning about 3D printing because it is easy to

Figure 3/ 3D Printer Filament

Source: allthat3d.com

print, very inexpensive, and creates parts that can be used for a wide variety of applications. It is also one of the most environmentally friendly filaments on the market today.

Nozzle (found attatched to your hotend)

Nozzles can be found in various diameters, the choice of which affects many aspects of your print, from precision to speed. **The goal is to balance speed and precision in your prints.**

Larger Nozzles (>0.4 mm)	Smaller Nozzles (<0.4mm)
✓ Faster print time	✓ High Precision
✓ Fewer maintenance / nozzle-related errors	✓ More maintenance - clogging

QUICK TIPS

People commonly use 0.4mm nozzles as it has a good balance between speed and precision. **As such, it is commonly recommended to go for 0.4mm nozzles.**

Extruder

The extruder is one of the most important parts of the printer. Also known as the cold end, **it is responsible for guiding and conducting the filament from the reel to the hotend for melting.**

The extruder is the upper portion of the extruder assembly. Its job is to transport and push the filament into the lower parts of the assembly, the hot end.

Figure 4 / Extruder of a 3D Printer

Source: https://3dprinterly.com/wp-content/uploads/2021/08/What-Are-the-Parts-of-a-Filament-3D-Printer-Extruder-3D-Printerly.jpg

Hotend

Figure 5 / Hotend

Source: https://8059blank.github.io/individual/3D-printers-102/

The hotend is also another essential part of the 3D printer. It is the part that melts, extrudes, and deposits the filament on the printer's bed for printing.

After the extruder feeds the filament into the hotend, the filament goes through a heated path called the melt zone. Here, the filament melts from the heat. Due to the pressure from the extruder, it is forced out of the small nozzle opening.

Build Surface / Print Bed

The build surface of the 3D printer refers to the platform on which the filament is deposited to form the print. Depending on the printer's model, the build surface can be stationary or move in a specified direction.

In 3D printing, the quality of the print is influenced heavily by the first layer and the build plate adhesion. So, the build surface plays a significant role in the printing process.

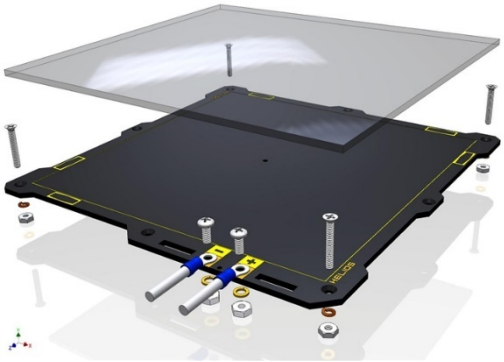


Figure 6 / Build Platform - Print Bed

Source: https://8059blank.github.io/individual/3D-printers-102/

Depending on the filament's material, there are different things to consider when using a print bed. These things include:

- ✓ **Heating:** Some print beds come with a heating pad attached to raise the temperature of the build surface. The increased temperature helps with first layer adhesion and warping.
- ✓ **Material:** The build plate's material also determines its performance. It determines how well the build plate holds up under heat, and how well the filament will stick to it.

Cooling (Part cooling fans)

Part cooling fans **cool the hot, freshly extruded plastic as soon as it exits the nozzle**. This eliminates various forms of print problems. However, several materials such as ABS will create more problems with a part cooling fan. As such, it is recommended always to check if a part cooling fan is needed for different materials. **For most filaments such as PLA, a part cooling fan is recommended.**

Figure 7/ Cooling fans

Source: https://8059blank.github.io/individual/3D-printers-102/

Print Display

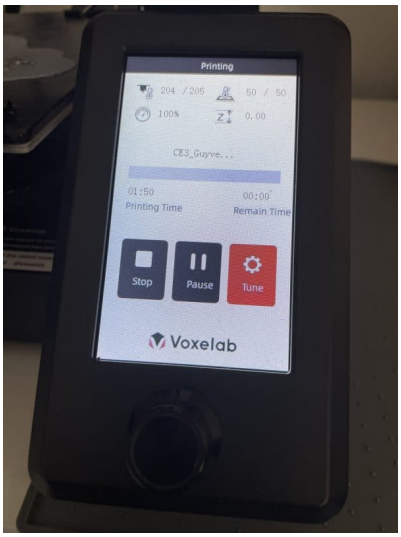


Figure 8 / Print Display

Source: https://3dprinterly.com/wp-content/uploads/2021/08/What-Are-the-Parts-of-a-Filament-3D-Printer-Control-Screen-3D-Printerly.jpg

The print display (or control box) is the Human Machine Interface of the 3D printer. It is how the printer's operator communicates with the 3D printer directly without using a PC or any device.

Using the control box, the operator **can start, pause, or stop printing.** They can also load the print files from external media like a USB stick or an SD card. It all depends on the sort of firmware loaded on the printer.

The control box interface can be a touchscreen or a plain LCD with physical buttons or a control knob.

The control box can also contain other sensitive electronics required for the proper functioning of the 3D printer. These electronics include the power supply unit, a motherboard, USB ports, and a Wi-Fi antennae.

3D printers require a proper setup to be used effectively.

1. Placement of your 3D Printer

It is essential to make sure printers are in an environment that allows for optimal use and performance. First, consider in which setting you will put your printers. There are multiple settings that you can place the printers in, and each set offers a different advantage. **If you plan on purchasing multiple printers, you can place them in a lab-type of environment**. It can also help educators streamline entire lesson plans over multiple 3D printers. If you plan on purchasing only one or a couple of printers, a typical classroom setup could be more beneficial as it gives students instant access to work on 3D printing design and print projects. However, be careful not to place the printers in a passage area or an open window, as open chamber printers are more prone to printing problems due to air currents. Closed chamber printers are safe; however, they are among the most expensive.

2. 3D Printer Material Selection and Storage

The type of 3D printing materials you choose will have an impact on your safety. Although all types of 3D printing materials produce VOCs or UFPs, there are some materials that are considered more harmful. While a material such as ABS produces potentially harmful levels of a VOC called styrene, a material such as PLA produces lactide, which is safer for students to be around and produces lower amounts of UFPs than the ABS material**. Therefore, we recommend the use of PLA or PVA materials in a classroom environment. PLA, which is usually made from corn starch, is also biodegradable, odorless, and does not require a heated build plate on the printer.** In addition, a material to consider when printing with a dual extrusion printer (a printer that utilizes 2 print heads at the same time) is PVA. Like PLA, PVA is safe to use in the classroom. It provides water-soluble support for printing complex models that require support for large overhangs, deep internal cavities, and intricate geometries. In addition, to keep your filament from being exposed to moisture, which could cause your print to warp or possibly fail during construction, try to store it in a cool, dry location (ideally in its original packaging).

It is recommended to use PLA or PVA materials, as they are odorless and do not require a heated build plate on the printer. They are also safer than ABS.

3. Proper Training for Educators

One of the most common criticisms from administrators who have 3D printers is that the printers are just "sitting in a closet" or "collecting dust." This is because teachers are not comfortable using the printers or struggle to find ways to integrate them into their lessons. Providing training gives educators the skills to integrate printers into their current curriculum. In-person professional development provides a great opportunity for educators to get hands-on training from 3D printing experts and to become familiar with the printers.

4. Tools and Supplies

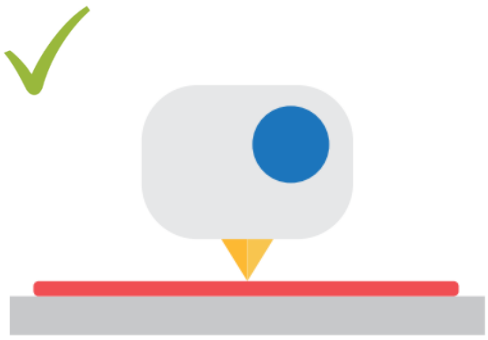
Below are some suggestions for tools and supplies that will make maintaining and using your 3D printers a little easier:

- **USB Stick** – This is an excellent tool for schools that have limited internet connectivity. Schools can store, organize, and print designs without the need for an internet connection.
- **Flush Cutters and Needle Nose Pliers** – Anytime you are printing a model that has an overhang, you will need to print the object with support material. These tools are designed to help you safely remove support material from the model after printing.
- **Craft Spatula** – Helps safely and efficiently remove prints from build plates using glue.

Calibration

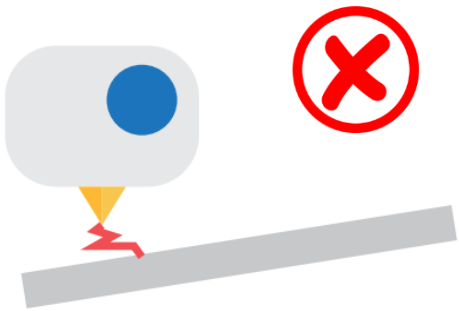
Getting your printer bed level flat might seem obvious, but it makes a real difference! **Calibration refers to the process of ensuring you have a level print bed that is the correct distance away from the printer's nozzle.** Although this does not have to do with preparing your files, it is one of the most essential aspects of the printing process.

Some printers may have an 'auto-levelling' function, which automatically performs this process. With other printers, you may have to manually adjust screws to ensure the print bed is in the correct position. Let's look at 2 scenarios to explain why calibration is so important.



In this scenario, **the print bed is completely levelled.**

When printing begins, the nozzle squashes filament onto the print bed. The squashing effect gives the model good adhesion to the bed, which is critical for a **successful** print.



If the print bed is not levelled, several problems can occur. At points where the print bed is too far away from the nozzle, the printer **will essentially be printing in mid-air, leaving messy strands of filament in the build area.** If the print bed is too close to the nozzle, the nozzle will scratch across the print bed and no filament will be extruded. This can also prevent the extruder module from moving freely.

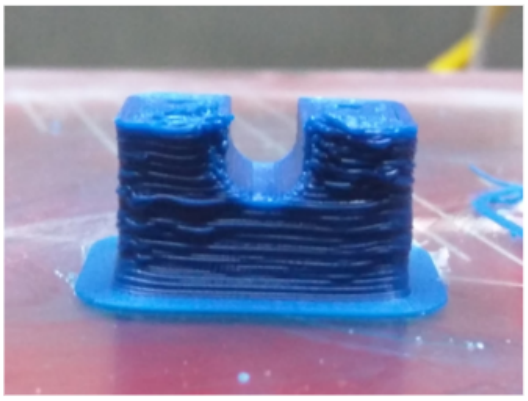
Temperature

The extrusion temperature is important. If your extruder is set either too hot or too cold for the filament you're using, you're effectively operating outside of the optimal printing conditions that the printing filament was designed for.

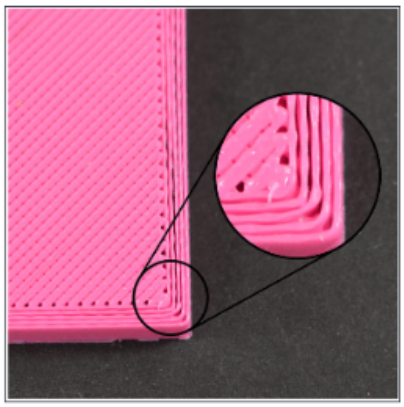
Check your manufacturing guidelines and run some tests a couple of degrees on either side of the optimal level to see the difference. You'll need to ensure that the first layer of print is hotter than the rest to ensure good adhesion of the print to the printer bed.

If your extruder is too hot, you'll get more strings of melted filament from the nozzle, and this could even lead to constant leaking of the filament onto your design.

If your extruder is too cold, you could find that the printed layers just don't stick together very well, and you'll find that you need to unclog the nozzle often.



Overly hot extruder



Overly cold extruder

Figure 9/ Sources:

Left Picture: https://www.reddit.com/r/FixMyPrint/comments/3usovy/print_bed_too_hot_something_else/,
Right Picture: https://www.simplify3d.com/support/print-quality-troubleshooting/under-extrusion/

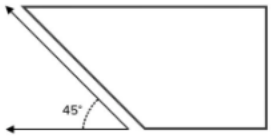
3D Printer Support Material

3D printing builds parts layer by layer, so there always has to be a previous layer to build upon. Depending on the specific 3D printing technology and complexity of the 3D model, you may need to produce your part with support structures.

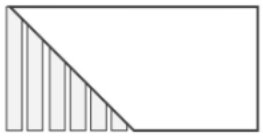
In FDM 3D printing, **support structures are necessary when the print has overhangs or features suspended in mid-air.** They allow successful printing of complex shapes **by propping up these otherwise unsupported areas.** 3D printer support material is simply the material in which these supports are printed.

However, support material is essential only when a feature **is printed with an overhang beyond 45 degrees.**

But, when is support material needed?



Overhang of **less** than 45 degrees
No support is needed

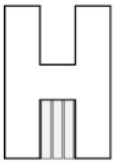


Overhang of **more** than 45 degrees
Support is needed

Let's imagine we have to 3D print models of the letter Y, H and T.

Although the "arms" if the letter Y are outstretched, they don't extend past 45 degrees.

No support is needed



- If the center bridge is **under 5 mm**

↓

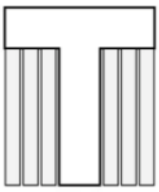
No support is needed ⊗

- If the center bridge is **over 5 mm**

↓

Support is needed ✓

The letter H, on the other hand, is a bit more complicated to 3D print.



Finally, let's take a look on the letter T.

Requires support for the top features extending from either side of the model. There is nothing for these arms to be printed on and **the material will fall down without support.** ✓

Here are how these models look when printed. The second image shows the result of the T printed without support. The surface has significant sagging and will require a lot of post-processing to clean up.

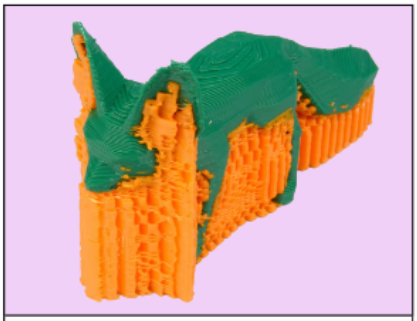
Models of Y, H and T printed with supports by an FDM printer

Without support, FDM deposits material in the air and fails to print the letter T

Figure 10 / Source: hubs.com

Post-Processing

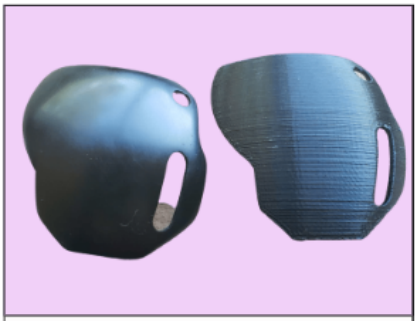
Almost every 3D print requires some sort of post-processing after it's printed. Post-processing can improve a printed part's aesthetics, but it can also improve its strength and other properties. There are many techniques to choose from, **from basic cleaning or gluing different parts of your model to painting and polishing it.** Depending on the application of the item, these techniques are usually the first steps in post-processing but can also be all you do, depending on how far you want or need to go.



Support Removal

Support removal is the most basic form of post-processing. Usually, support removal doesn't require much effort, unless there are supports in tight corners or other hard-to-reach places.

Support structures are 3D printed to have lower density than the main build. As such, they can be easily removed from the 3D print by either carefully pulling them off by hand, or for harder-to-remove supports, by use of needle-nose pliers, dental picks or tweezers.



Sanding

Apart from support removal, sanding is the most common form of post-processing. **Generally, FDM 3D prints can have a slightly rough surface, and sanding is the easiest way to smooth it.**

After printing, a part might have a few blobs left on its surface, or there might be some marks after you've removed supports. The ideal way to remove such blemishes is by using sandpaper. It's always best to start with low-grit sandpaper (150-400) and move towards higher grit sandpaper (up to 2,000) in a few stages of sanding.

Gluing

Luckily, 3D prints made with PLA can be merged by gluing. This is generally used when something can't be printed in a single piece.

The best glue for PLA filament is standard super glue. It's widely available, forms a strong bond between printed parts within seconds, and dries clear.

Finally, to have the best result, techniques such as painting, smoothing, polishing, or dipping are performed. The extra effort that goes into performing finishing techniques certainly pays off in the end. By applying these techniques, you'll be able to get rid of visible layers and create the smoothest possible surface.

Safety Rules

3D printing is a relatively new technology and industry and is also one of the latest technologies to enter schools. Before the purchase of 3D printers for a school, it is essential to consider all facility, site, and safety requirements of the hardware and the thermos-plastics to be used so that any risks can be minimised.

To keep yourselves and your kids safe when using 3D printers, you should:

- Use the 3D printer in a **well-ventilated** environment, where the odors and emissions can leave the space and open the windows and doors. **Do not use it in a closet or enclosed space.**
- **Do not allow children – or anyone – to hover over the printer or to stand too close to it.** Most units take at least four hours (or overnight) for the printer to construct the object, so turn it on, leave and return to pick it up later when it's finished.
- **Purchase low-emitting filaments.** Look for certification that the 3D printer you are buying meets low-emission standards. If you already have one, ask the manufacturer for their data.
- If you smell an odor from the machine, step back and be careful because those vapors indicate emissions that can be dangerous contaminants.
- **Keep people away from the printer,** especially if they have asthma or allergies, ensuring that all children are risk-free.

Wear Safety Goggles

This will lower the risk of eye injury when using a 3D printer.

Do not touch

Depending on the type of 3D printer and the material that's being deposited, it may reach a temperature of up to 200 degrees Celsius. Therefore, touching the 3D printer can cause a painful burn.

Control the Temperature

Controlling the temperature of the 3D printer can lower the risk of injury. Materials are designed to cure and harden at specific temperatures.

Ventilation

With proper ventilation, any toxic or harmful fumes will be flushed away from the surrounding indoor space so that they aren't inhaled.

With all this information in mind, it is not recommended to leave your kids unattended when 3D printers are in operation.

If you purchase a printer that is not enclosed fully, you should keep it in a well-ventilated room to avoid the hazardous dangers it might pose to the surrounding.

Source: 3dprintschooling.com

It is also advisable to **avoid gathering around the printer** once it has been set operational to avoid breathing in dangerous particles that come from the printer.

References

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