

3D Printing Guide for Teachers



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Hello from PrintLab

It's an exciting time for teachers looking to integrate 3D printing in the classroom and it is our mission at PrintLab to make the process as easy, enjoyable and valuable as possible.

We hope you find the information in this guide useful and if you require any advice or support, please do not hesitate to contact us at hello@weareprintlab.com

Let's inspire the next generation, [together.](#)

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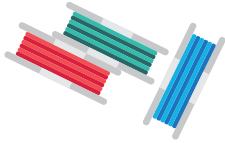
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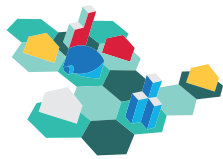
043 3D Printing Solutions



Enjoy the journey!



Support



1.

Introduction

In the first chapter of this guide you will be given an overview of the 3D printing industry along with the 3D printing process. The aim of this chapter is to provide you with the essential background knowledge to enable you to confidently talk about 3D printing to your students.



Introduction to 3D Printing

3D printing is a manufacturing process where successive layers of material are laid down on top of each other in an additive process. Although 3D printing is often spoken of as a new technology, it has actually been around for over 30 years. Around 8 years ago, patents around 3D printing began to expire and 3D printing opened up to mass audiences. The landmark point for its commercial adoption came from the open source RepRap project - a 3D printing initiative with the goal of creating low cost, self replicating 3D printers. Being open source, all the files were freely available online and in the following years we saw a large number of startups creating their own 3D printers, inspired by the RepRap project. Let's take a look at the steps required in the typical 3D printing process:



1. 3D model file

It all begins with a digital 3D model of a design. There are hundreds of software programs that enable you to design in 3D. Some free ones that are great for educators are SketchUp, TinkerCad and Fusion 360.



2. Slicing

The 3D model file (typically an STL file) is then split up into very fine layers in a software program called a “slicer”. The output from the slicer is a code, which tells the 3D printer how to move and where to lay down material.



3. 3D Printing

Once the code is loaded to the 3D printer, it will begin the production process. One layer is created at a time until the model is complete. This can take minutes or hours depending on the size of the model.



4. Post-processing

Depending on the type of 3D printer and the model file you print, there may be a requirement for some post-processing. Examples include removing support material, cleaning and sanding.

3D Printing Types

There are various types of 3D printers that work using different technologies and materials. However, all 3D printers have something in common - they all build up an object layer by layer. Let's take a look at 4 popular 3D printing methods:

1. FFF (Fused Filament Fabrication)



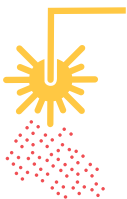
This is the most popular type of 3D printer for educators and they work by melting plastic filament and depositing it onto a print bed, where it solidifies. Additional layers are printed on top of each other until the model is complete. Types of plastic include PLA, ABS and composites that combine plastic with wood, copper, bronze and several others.

2. SLA/DLP (Stereolithography/Digital Light Processing)



SLA/DLP machines utilise light sources to cure a liquid photopolymer. A print bed is submerged in resin and the light is used to solidify certain areas. Once a layer has solidified the print bed will move, allowing the light to cure the next layer.

3. SLS (Selective Laser Sintering)



Selective Laser Sintering works in a similar manner to SLA/DLP technologies but the light source (laser) is used to fuse powdered material together. The most common material for SLS printers is nylon.

4. Material Jetting



Material jetting uses a similar technology to a standard inkjet printer. The difference being that the material used is a liquid photopolymer that is cured by a UV light source once it hits the print bed.

There are several other 3D printing technologies available but for the purpose of this introductory guide, we'll be focusing on FFF 3D printing.

Why 3D Printing?

1. Less Waste

In traditional 'subtractive' manufacturing, a block of material is cut down to create an object, which can result in up to 90% in waste material. Because 3D printing uses an additive process, little or no material is wasted.

2. Customisation

Products such as pens, phone cases etc are created on assembly lines because it is cost efficient to produce them in this way. With 3D printing, each design can be different and there will be no additional tooling or assembly costs involved.

3. Complex Geometries

Subtractive manufacturing techniques have limitations in the geometry of products. Machines simply cannot cut or mill certain patterns but with 3D printing, these limitations don't exist.

4. Efficient Prototyping

Imagine being able to design a concept and hold a prototype of this within a matter of hours. 3D printing enables this at just a fraction of the cost of creating prototypes through traditional methods.



3D Printing Limitations

1. Speed of Large Production Runs

3D printing is a great tool to obtain prototypes and low quantities of products quickly because there is no setup required. For large production runs, 3D printing is not a viable option because of the speed of the actual printing process.

2. Cost of Large Production Runs

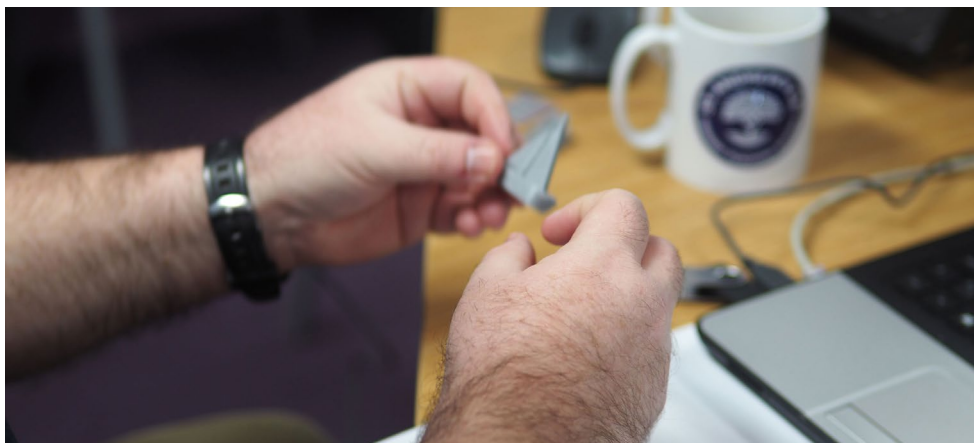
In traditional manufacturing, the cost of production decreases with the amount of products being made. With 3D printing, this is not the case because cost is based on material usage. Therefore large production runs can be very expensive.

3. Materials

More and more new materials are becoming available for 3D printers but there is still a very long way to go before there are anywhere near the amount of options available through traditional methods.

4. Accuracy

In some industries such as engineering and automotive, small components require extreme precision. Although 3D printers can be precise right down to around 10 microns, subtractive methods can still achieve better precision.



Uses in Industry

Now that you have some background knowledge of 3D printing, let's take a look at how 3D printing is used in various industries.

Architecture

Typically, architects can spend days creating physical models to explain their designs to clients. Using modern technology, they can use their existing CAD drawings to rapidly create a 3D model and print it in 3D. Not only do they save time but complex geometries that can't be modelled by hand can be produced efficiently and at a low cost.

Prosthetics

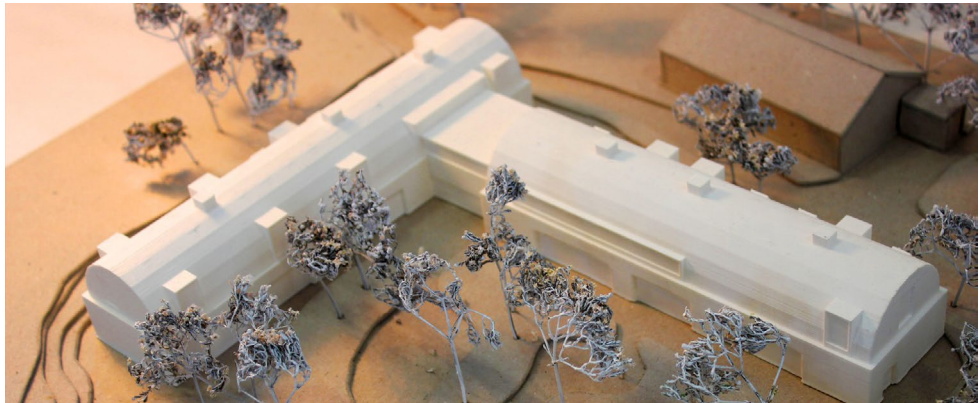
The amazing e-NABLE project use desktop 3D printers to create custom prosthetics for children at a production cost as low as \$50. Being such a low cost option benefits children in particular because they grow out of their prosthetics quickly. Additionally, 3D printing allows children to choose custom options for their prosthetics such as superhero designs!

Medical

One of the key benefits of 3D printing is the ability to customise objects at no extra cost. The medical sector is taking advantage of this in various ways and one prominent field is that of hearing aids. The process begins by taking a 3D scan of the patient's ear, which ensures an accurate 3D print can be made that has a perfect fit for that specific patient.

Dental

Combined with 3D scanning technologies, dentists can now 3D print moulds, visual aids, bridges, crowns, guards and more. 3D printing eliminates the need for manual tasks, which saves weeks of time and similarly to hearing aids, each product is accurately tailored to the patient. There are many 3D printers designed specifically for dentists.



Product Design

3D printing enables product and industrial designers to create prototypes within hours as opposed to weeks through traditional methods. The cost to create a prototype can be in excess of \$10,000 when you consider the tooling required for processes like injection moulding. With 3D printing, prototypes can be achieved at a fraction of the cost.

Aerospace

3D printing for aerospace purposes allows complex geometries to be created with no waste material and no tooling required. This results in innovative functional parts and millions of dollars are saved. GE aviation have even started testing the largest jet engine ever built. The engine is said to be more efficient, advanced and powerful due to its 3D printed components.

Hobbyists

Desktop 3D printers can now be acquired for under USD\$500, which has gained the interest of many hobbyists. From 3D printing toy characters to functional items for the home, we're seeing anyone and everyone becoming part of the "maker movement". Many industry experts have predicted that in the next ten years, most households will have a 3D printer.

3D Printing in the Classroom

The 3D printing industry is set to grow from \$7.3 billion in 2016 to \$21 billion in 2020, and 3D printing expenditure in education is set to grow from \$200 million in 2015 to \$500 million by 2019. But what is the relevance of the macro scale for you, as a teacher? These facts are important because they will have a direct effect on the very students you teach. As you saw on the previous page, 3D printing is making huge waves in so many different sectors. The innovative technology is going to disrupt the design process and the supply chain that we see today.

Because of this, it is essential that we prepare students for the challenges of tomorrow. Over the next 5-10 years, we'll begin to see further advances, particularly with materials, software and printing speed. These advances will bring on what has been described as the next "industrial revolution" and the people heading up this revolution will be those who are currently in education.

In addition to preparing students for their future careers, 3D printing revolutionises the way students engage in the classroom.



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Introduction

The fact that 3D printing technology still needs developing actually plays to our advantage - why? Because it empowers students to solve problems and truly learn the ins and outs of how this exciting technology works. One of the biggest questions we get asked is “what can I do with a 3D printer?” - and we usually answer this question with, “what can’t you do with a 3D printer!”.

Many people seem to think that a 3D printer belongs in a D&T classroom, but what they fail to recognise is that 3D printing is seeing massive success in all areas of education. Take exploration of fossils in a History lesson for example, what better way to teach this than to 3D print examples that students can examine, hold and understand. Physics is another example, where students could print their own model boats, some hollow and some solid, to experiment with what floats, what doesn’t and why.

There is an enormous scope of opportunity with 3D printing and we are excited to assist you in your journey.



3D Printing by Subject

Maths

Models of equations and volumes can be 3D printed to assist students in understanding maths for real life applications. Imagine printing a Fibonacci spiral that students can observe and hold!

History

Help students understand what it was like to live in various eras by 3D printing replica artefacts and statues. There are hundreds freely available from websites such as Thingiverse and YouMagine.

Geography

Understanding topography can be difficult by reading 2D maps, so why not recreate them in 3D. The below image shows a lesson project where students design and 3D print a 1:50,000 scale contour model of Mount Everest.

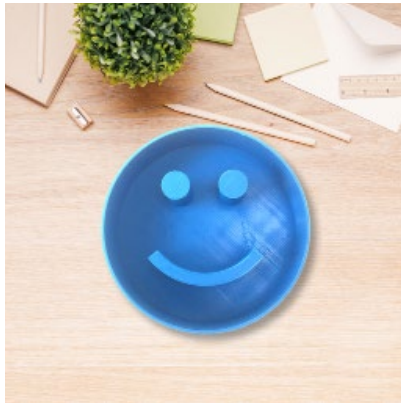
Science

Explore density, mass, projectiles and much more by allowing students to design objects like balloon powered boats, rockets and rubber band powered cars. It's a sure way to get them thoroughly engaged in design and problem solving.



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Introduction



Design Technology

Combine traditional woodworking with 3D printing, offering a fresh and modern way of designing. The above image shows a lesson where students make a workshop stool with 3D printed connectors.

Engineering

Prototyping is a huge part of any engineering process. With 3D printing students can bring their ideas to life and create several iterations of their designs to achieve the best functional results.

Art

3D printing enables us to create complicated artistic forms that can't be produced by using traditional methods. This opens up new innovative opportunities for students to explore.

Food Technology

Food moulds and cookie cutters are a great way to engage students, whilst teaching them new design skills. We are also beginning to see a range of food specific printers such as chocolate 3D printers!

2.

Getting 3D Printable Files

Now that you have some initial background knowledge, it's time to look at how we actually obtain a 3D printable file. There are several ways to do this and in this chapter we'll take a look at downloading pre-designed files, creating files in CAD software and 3D scanning physical objects.

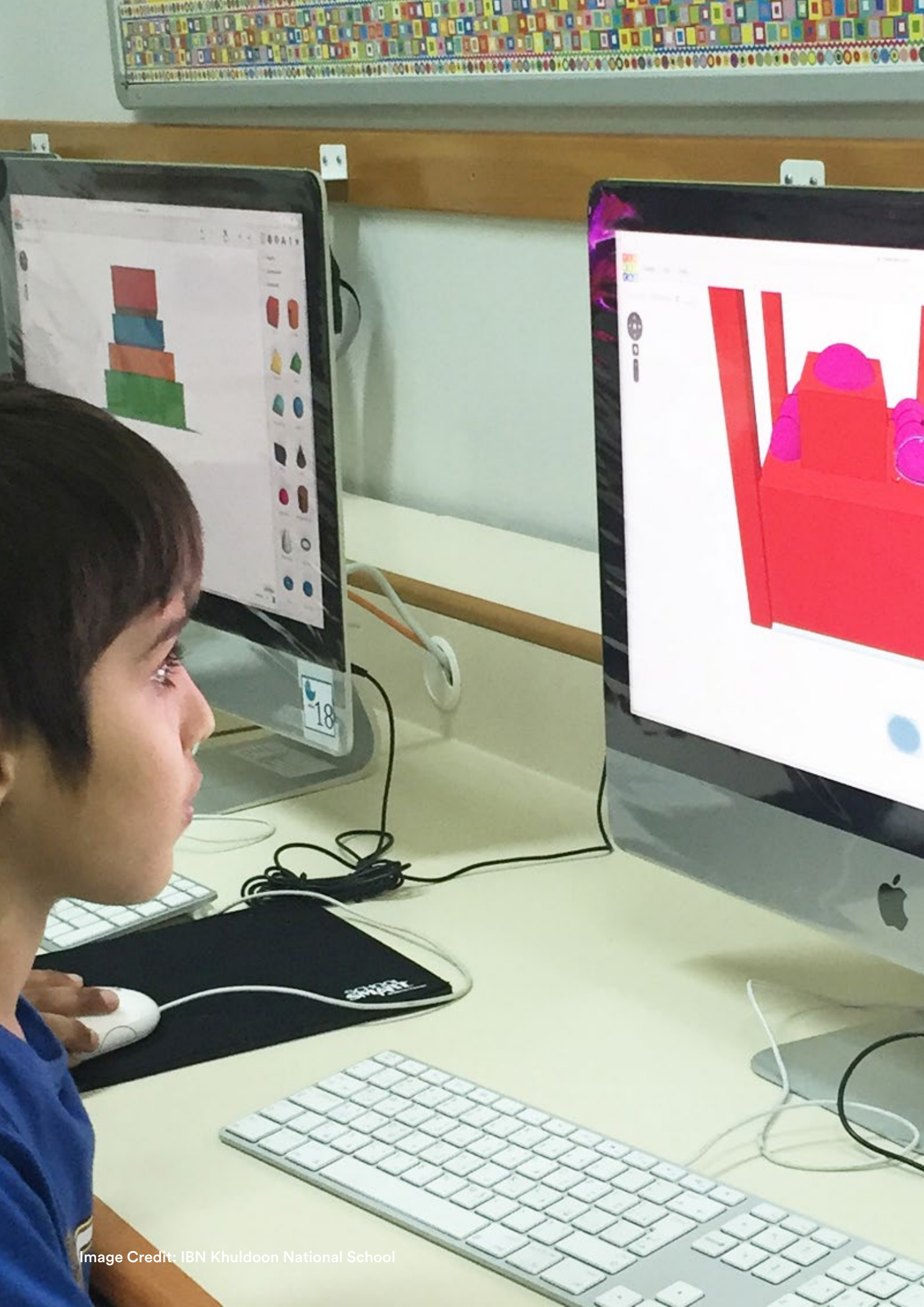


Image Credit: IBN Khuldoon National School

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Getting 3D
Printable Files

Downloading Models

The easiest way to obtain a 3D printable file is to download pre-designed files. Simply head to one of the below websites and there will be hundreds of free models available for download. The most common 3D printing file type is known as an STL. Once downloaded you can open the STL's in your 3D printer's software where you will select various parameters before 'slicing' the model and sending it to the 3D printer.

3DKer - www.3dker.com

3DKer

3DKer is Shining3D's online platform. It is a thriving community which gives users free access to thousands of 3D printable models all over the world. The 3DKer team want to bring an extraordinary experience to the general public.

Thingiverse - www.thingiverse.com



Thingiverse is an online community for discovering, making, and sharing 3D printable things. As the world's largest 3D printing community, they believe that everyone should be encouraged to create and remix 3D things, no matter their technical expertise or previous experience.

YouImagine - www.youmagine.com



YouImagine is an online community of 3D printing enthusiasts who wish to work together to share, remix and make better 3D printed things. YouImagine facilitates this community, empowers and gives you the tools you need in order to improve, invent & make.

MyMiniFactory - www.myminifactory.com



MyMiniFactory, which launched in 2013, is one of the world's leading curated social platforms for 3D printable objects. On MyMiniFactory, you can find tens of thousands of 3D designs ready for you to download for free. These will work with any desktop 3D printer, and they have tested every single one so that it is guaranteed to print!

Downloading Tips

With the amount of freely available models on the internet, you might struggle finding the model you want. In addition, most of the sites allow anyone to upload designs so you want to make sure that they are 3D printable. Here are some tips for finding the right model and making sure it is printable:



Check the Path Viewer in your Slicing Software

Most slicing software packages have a 'path viewer' or 'layer viewer' that allow you to drag a slider to see the actual path the printer will take when printing. Be sure to check this prior to starting a 3D print to ensure everything looks correct



Check out the Education Sections

Most of the websites listed on the previous page have a specific section for education. There are many teachers around the world who are active in sharing their designs. You may also be able to contact the designer using information provided on the website to ask for advice and tips!



Look at Popular Models and Read the Comments

Next to each available model you will see how many views and downloads each one has. Popular models are likely to be well-designed and 3D printable. In addition many users leave comments on the designs - reading these may help you learn about the best settings for that specific model.



Use the Search Function

All of the sites listed on the previous page have a search bar where you can type in keywords to find models. This can save you a lot of time if you know the type of model you want to print. You can even type in subject areas such as 'Maths' or 'Physics'.

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CAD Software

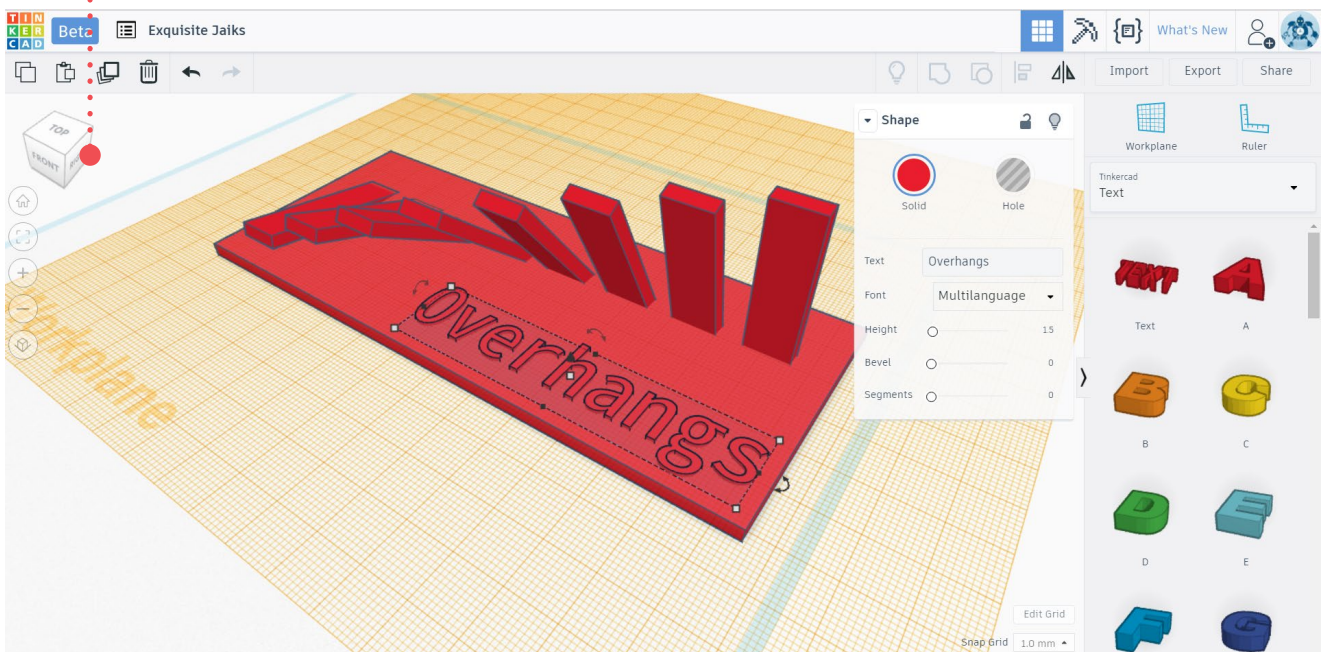
Getting 3D
Printable Files

CAD stands for Computer-Aided Design Software and refers to computer programs that are intended for design purposes. They can either be 2D, 3D or both and most 3D printable files are created with CAD software. CAD was invented in the 1960's and over the years it has replaced manual drafting methods because of its speed, accuracy and ability to easily make amendments.

CAD is used in a whole range of industries such as architecture, engineering, animation, medical and education etc. In recent years CAD software has become extremely accessible and there are now many free programs available to download. In addition to being free, there has been an increase in the availability of software packages suitable for those with no experience.

Tinkercad

We advise that you try out a range of the options listed on the next page. You will most likely find one that you think is best suited for your students, but it is also worth noting that different software packages are better for certain types of models. For example there are some programs that excel in digital sculpting and others that perform better at sketching and extruding surfaces. For this reason we recommend keeping an open approach and encourage students to experiment with various software options.



CAD Options for Schools



Tinkercad - www.tinkercad.com

Tinkercad is a simple, online 3D design and 3D printing app that can be used through a web browser. It is a great tool for educators at the beginner/intermediate level. Shapes are the basic building blocks of Tinkercad. A shape can add or remove material and you can import your own or work with existing shapes. Shapes can then be moved, rotated or adjusted freely in space. You can also group shapes together to create detailed objects as complicated as you like.



SketchUp - www.sketchup.com

SketchUp is another simple design software that differs from Tinkercad in various ways. Firstly it is an offline software, meaning you can work directly from your desktop with no internet connection. In SketchUp you start by drawing lines and shapes before pushing and pulling surfaces to turn them into 3D forms. You can stretch, copy, rotate and paint to make anything you like. SketchUp is used by a wide range of people, from complete beginners to architects and product designers.



Fusion 360 - www.autodesk.com/products/fusion-360/overview

Fusion 360 is a cloud-based 3D CAD, CAM, and CAE platform for product development. It combines industrial and mechanical design, simulation, collaboration and machining in a single package. The tools in Fusion 360 enable fast and easy exploration of design ideas with an integrated concept to production toolset. Fusion 360 is an advanced design software but the amazing tools it provides makes it a top choice for educators.



Meshmixer - www.meshmixer.com

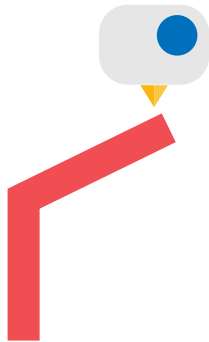
Meshmixer is state-of-the-art software for working with triangle meshes. If you need to clean up a 3D scan, do some 3D printing, or design an object that fits something else, Meshmixer can help. Think of it as a sort of “Swiss Army Knife” for 3D meshes. It excels above the other software packages mentioned on this page when it comes to editing 3D scans.

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Getting 3D
Printable Files

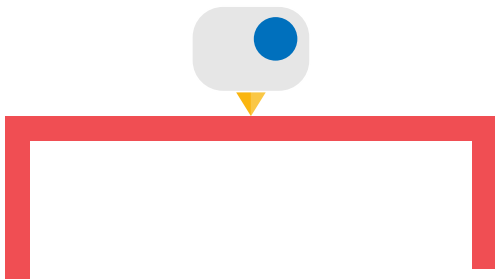
Design Considerations

There are several aspects of 3D design that need to be considered when creating models for 3D printing. 3D printers have their limitations and it's important to highlight these in the classroom. Let's take a look at some design considerations required for FFF 3D printers.



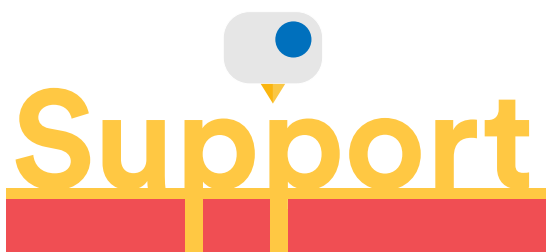
1. Overhangs

FFF 3D printers require at least a partial surface or layer to print on top of, therefore problems may arise when printing steep overhanging features. The larger the overhang angle, the poorer the surface quality.



2. Bridging

Bridging is essentially an overhang but the printer 'bridges' across two points. The larger the bridge, the poorer the quality.



3. Support

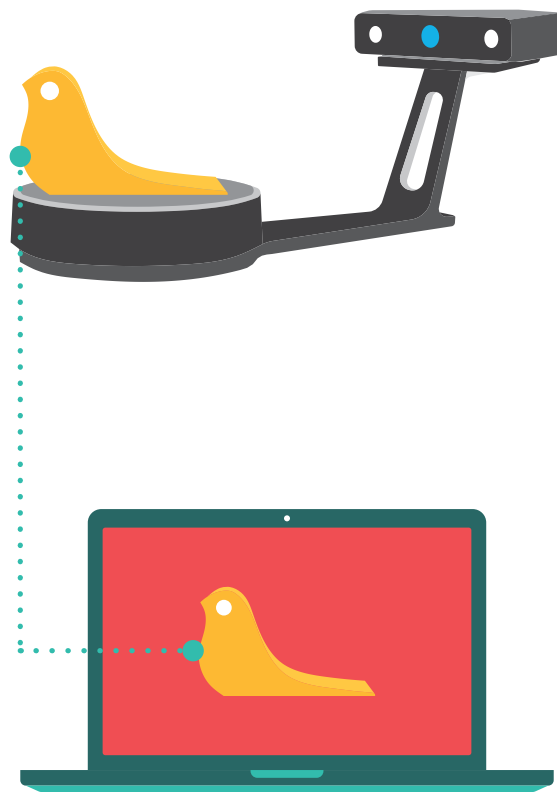
To help with overhangs and bridging, support material can be generated by most slicers. This is temporary structure that is peeled off after printing but the surface quality is usually compromised.

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Getting 3D
Printable Files

3D Scanning

3D scanning is the process of collecting 3D data of an object's shape and appearance. A 3D scanner can turn physical objects into digital 3D models!



3D scanning opens up a world of opportunities that include:

- Preservation of artefacts
- Ability to reverse engineer products
- Ability to recreate models in a wide range of materials
- Accurate inspection of objects (e.g. precise measurements of distances and surfaces)
- Designing customised products (e.g. prosthetics that fit a patient perfectly)

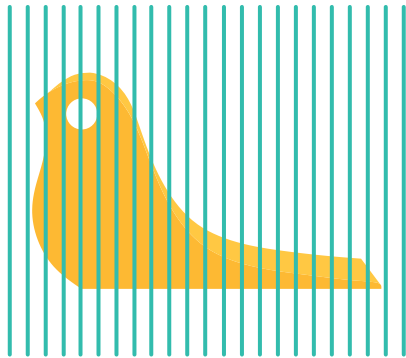
By introducing students to 3D scanning at such an early stage, you can easily obtain 3D files and further down the line you can develop lessons around editing 3D scans for functional applications.

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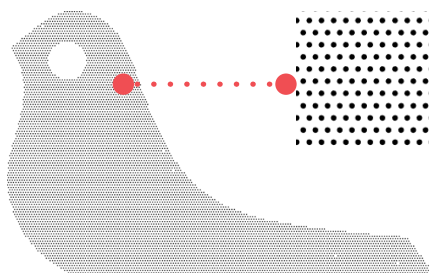
How 3D Scanning Works

Getting 3D
Printable Files

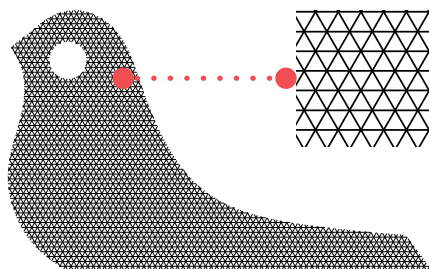
There are various types of 3D scanners - some use laser technology, some take photos around an object - but in this guide we're going to look at **Structured Light 3D Scanning**. We believe that structured light 3D scanning is the most suitable for the classroom because it is a completely safe light source, as opposed to laser technology that can be harmful to the eyes.



1. Structured Light Scanners project a pattern onto an object. Built in cameras measure the edges of the pattern and through triangulation they can determine the angle and distance of the object from the 3D scanner.



2. This results in something called a point cloud. A point cloud is a set of 3D data points created by a 3D scanner. It cannot be 3D printed because there are no surfaces, only tiny dots in a 3 dimensional space.



3. Models need to be watertight to be 3D printed. Most 3D scanning software packages can easily convert a point cloud into a 3D printable STL file through the click of a button! The software will essentially join up all the dots in the point cloud to create a solid surface.

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Scanning Considerations

Getting 3D
Printable Files

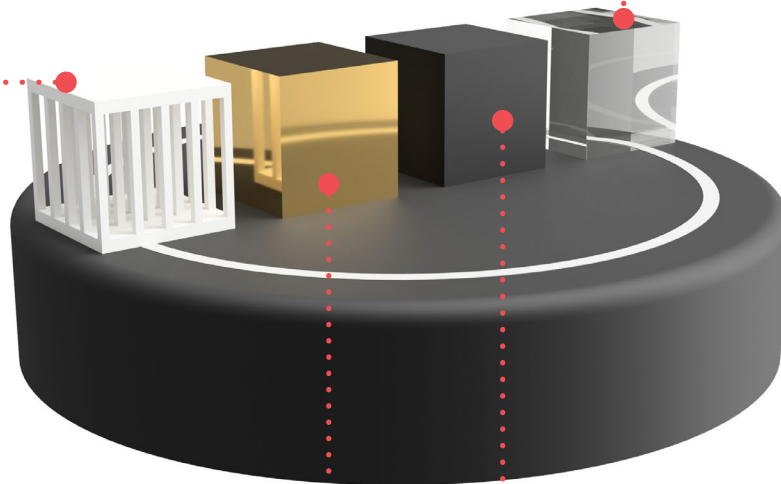
It is important to understand that there are certain limitations with all light-based scanners. The below diagram shows different objects that may be difficult to scan:

Complex Internal Geometries

The projector and cameras must have a direct line of sight to the surface in order to record data from it. Therefore models with complex internal geometries or deep holes are difficult to scan.

Transparent/Translucent Objects

When the light and pattern from the projector hits a transparent or translucent object, it will pass through the surface. Therefore any data recorded by the cameras will be inaccurate. A common way to prepare models that are transparent/translucent is to spray them with temporary white paint or cover them in white powder.



Shiny Objects

When the light and pattern from the projector hits a glossy surface, it will reflect - this also causes inaccuracies. Similarly to transparent objects, shiny objects can be prepared for 3D scanning by applying white paint or powder.

Very Dark/Black Objects

When the light and pattern from the projector hits a very dark surface, it will be absorbed. The scanner is unlikely to pick up much data from a black object. Again, they can be prepared with white paint or powder.

3D Scanning Applications

Museums

3D scanning is widely being used in museums. Perfectly identical, richly detailed, true-to-scale copies of an ancient artefact or a sculpture also represent an opportunity, not only to preserve but to teach and allow those interested to get hands-on without risking damage to a priceless item.

Medicine/Health

3D scanning enables the design and production of a prosthetic limb that is measured to a remarkable accuracy, meaning maximum comfort, mobility and reduction in pain. Coupled with 3D printing, this process is a fraction of the time and cost of traditionally used methods.

Engineering

Another area with huge potential for 3D scanning is engineering. The ability to scan any object and then use CAD for modification makes both reverse engineering and rapid prototyping an extremely streamlined process. Detailed measurements can be performed and investigation in to mechanical properties is simplified.

Science/Research

Researchers at Drexel University have recently begun 3D scanning and printing dinosaur fossils and building their very own scaled-down robotic replicas. The objective is to see how the dinosaurs bones interacted with one another to create movement and respond to environmental stresses.



Architecture

The ability to scan and analyse buildings in high detail makes 3D scanning a hugely attractive proposition when conducting architectural surveys. 3D scanning provides the user with extremely accurate measurements and the ability to fully utilise, visualise and modify data with CAD.

Design

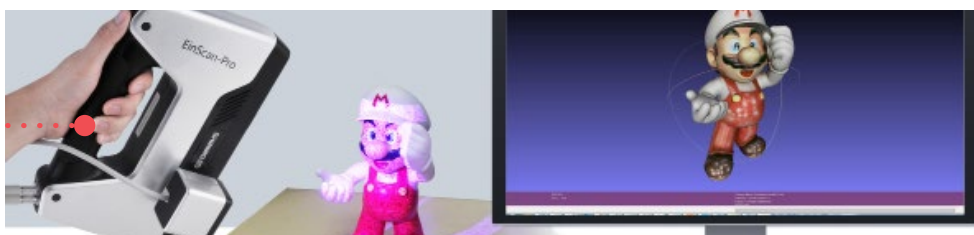
As we continue to design and develop more effective materials for a range of purposes, we commonly look to mimic natural materials for their superior properties, be it plant structures or even fossils. What better way to study these complex arrangements and create a new design than through scanning and studying in high resolution.

Full Body Scanning

Since no two human bodies are the exact same, what better subject to use when creating a unique 3D model. There are numerous services opening up around the world that enable the user to be 3D scanned and take home their very own 3D printed replica model of themselves.

Virtual Reality/Animation

Major games developers have been creating gaming characters with 3D scanning for some time, however as ease-of-use and affordability improves, more small-medium game and app developers can use 3D scanning to give gamers a better user experience.



The Initial Value of 3D Scanning

Whilst students get to grips with CAD software, 3D scanning is an amazing way to easily obtain files for 3D printing. A popular option for educators is to run a series of hands-on activities where students create models out of clay or plasticine. These objects can then be placed onto a turntable 3D scanner that will give a 3D printable output (STL file). The STL files can then be uploaded straight on to your 3D printer's slicing software, where you can explore a range of options before 3D printing your students' creations.

There can be many lessons taught during this process, such as how obtaining a digital file of a design allows you to explore a variety of manufacturing techniques with different materials. For example, you may wish to create some versions in wood using CNC machinery and some models in plastic using a 3D printer.



Progressing 3D Scanning in the Classroom

As explained on the previous page, 3D scanning is great for obtaining 3D printable files, but its value goes much further than that. Once students become familiar with the 3D scanning process, you can introduce them to more advanced techniques that involve modifying 3D scans.

Take a look at the below image, which shows a 3D printed pen. The pen was created by clay modelling the shell before 3D scanning it. CAD software was then used to edit the model so an ink cartridge can slot into the middle of the shell when 3D printed.

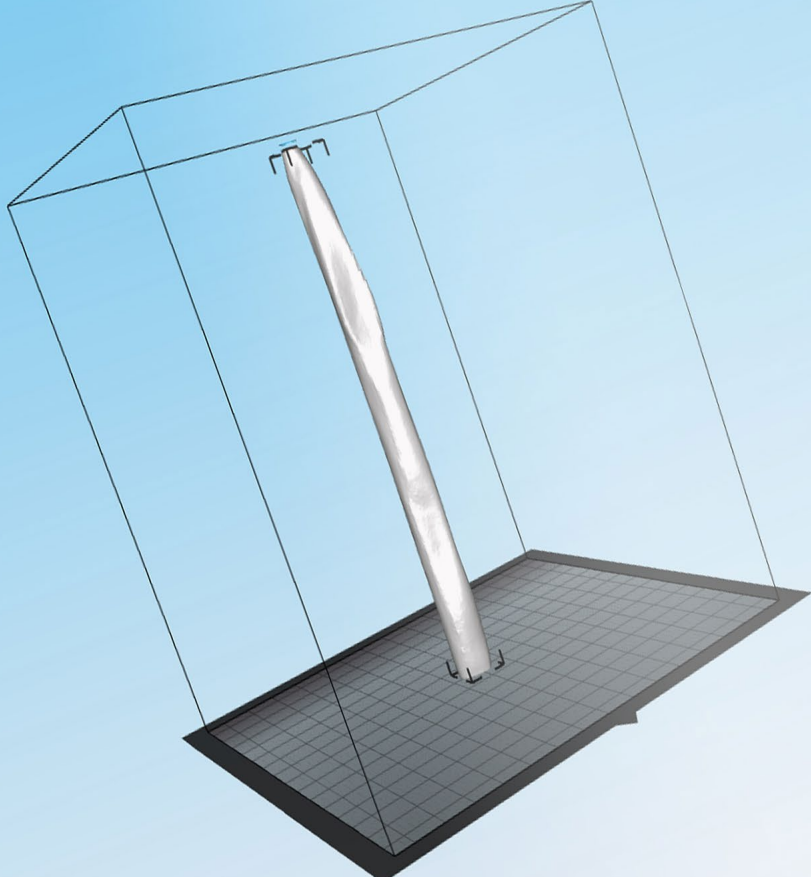
This exact same process of scan, edit, manufacture is widely being used in the product design industry. By introducing students to this process at an early stage, they can relate to real-world applications - something that is essential to prepare them for their future careers.



3.

Preparing Files for 3D Printing

Having obtained an STL file, the next step is to upload it to your 3D printer's slicing software. Within this software you can change various parameters to your requirements. In this chapter we'll look at some considerations and tips to help you prepare models for 3D printing.

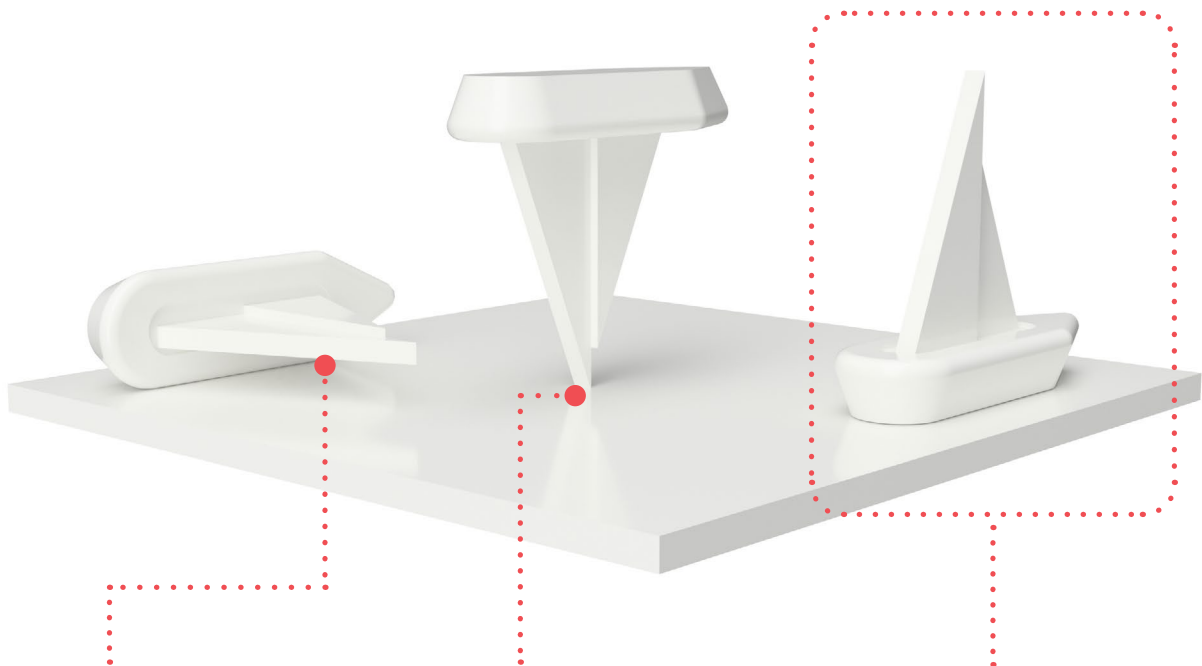


023

Model Orientation

Preparing Files for 3D Printing

One of the most important things to do within slicing software is to optimise the orientation of your model for 3D printing. Take a look at the below examples of a sailing boat model.



Excessive Overhangs

If we placed the sailing boat model in this position, the resulting print would be very poor quality. If you look at the sails of the boat and imagine the printer creating this section, you may realise that the printer will essentially be printing in thin air. There is no material under the sail to print on top of. Generally, the bigger the angle and area of the overhang, the worse the surface quality.

Poor Bed Adhesion

In this scenario only a fraction of the model is in contact with the print bed. The software can generate a raft (base structure) for this to be printed on but this is unlikely to stop the print from coming off the print bed when printing. Good bed adhesion is critical to all 3D prints and in order to achieve this, there needs to be a relative amount of surface area touching the print bed/raft.

Correct Orientation

For the sailing boat model, this is the best orientation. There are no areas with steep or large overhangs and there is a large flat surface touching the print bed. If you cannot avoid overhangs by rotating the model, you should orientate it to the position with the least overhangs. Most slicing software have a function called 'Support', which is discussed on the next page.

024

Support Material

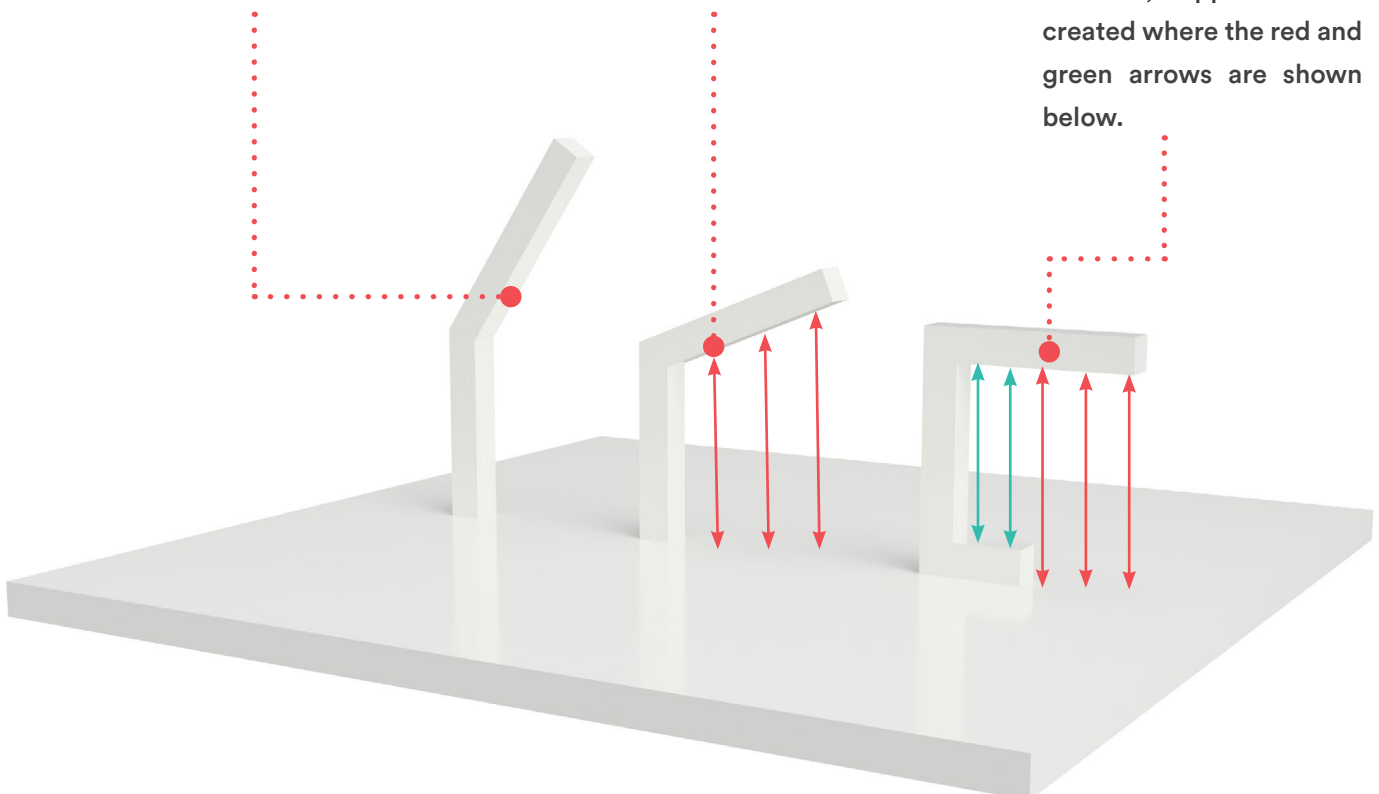
Preparing Files for
3D Printing

Most slicing software packages can automatically generate 'support structure'. This is where the printer will create a temporary structure of lines underneath overhanging features, which is peeled off when the print has finished. The temporary structure enables FFF printers to print steep overhangs and bridges but the surface quality when removed will not be completely smooth. Some higher-end machines have 2 nozzles and allow you to print support in a soluble material such as PVA that dissolves when the model is submerged in water.

The overhang angle here is less than 50 degrees. This is generally acceptable and there will be no compromise in surface quality, therefore support is not required.

Because this object has a steep overhang, support material will be required. It may be possible to print this without support but the surface quality will be affected.

Most slicing software packages have the option to build support from the print bed only or from everywhere. If print bed only is selected, support will be created where the red arrows are below. If support everywhere is selected, support will be created where the red and green arrows are shown below.

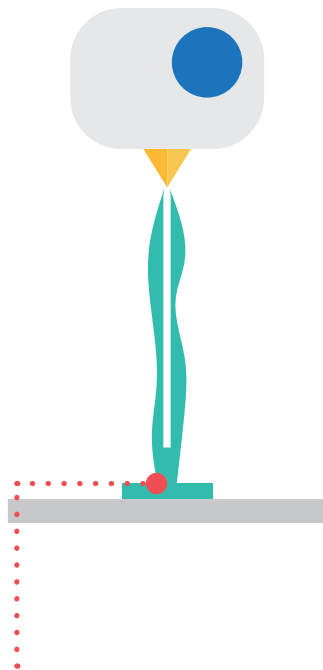


025

Print Bed Adhesion

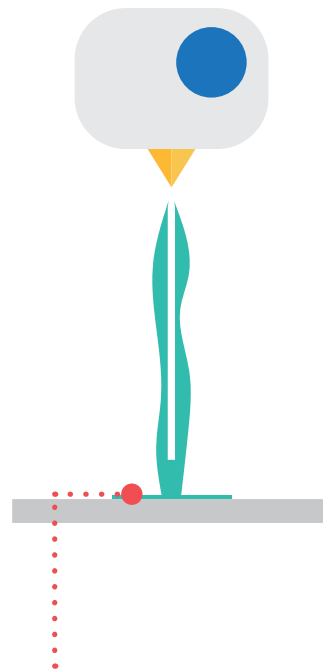
Preparing Files for
3D Printing

When 3D printing, a common problem is that models sometimes detach from the print bed due to the shrinkage effect of plastic. To help models stick to the print bed, slicing software packages generally have the below functions:



Raft

Rafts are temporary print surfaces that help the model stick to the print bed. Rafts are automatically generated by the slicing software and tend to be relatively thick bases. When the print is completed you will peel off the model from the raft.



Brim

A brim is similar to a raft in that it helps models stick to the print bed. However, instead of being a thick base, brims are usually a single flat layer that wraps around the model, giving it a larger surface area to stick to the print bed.

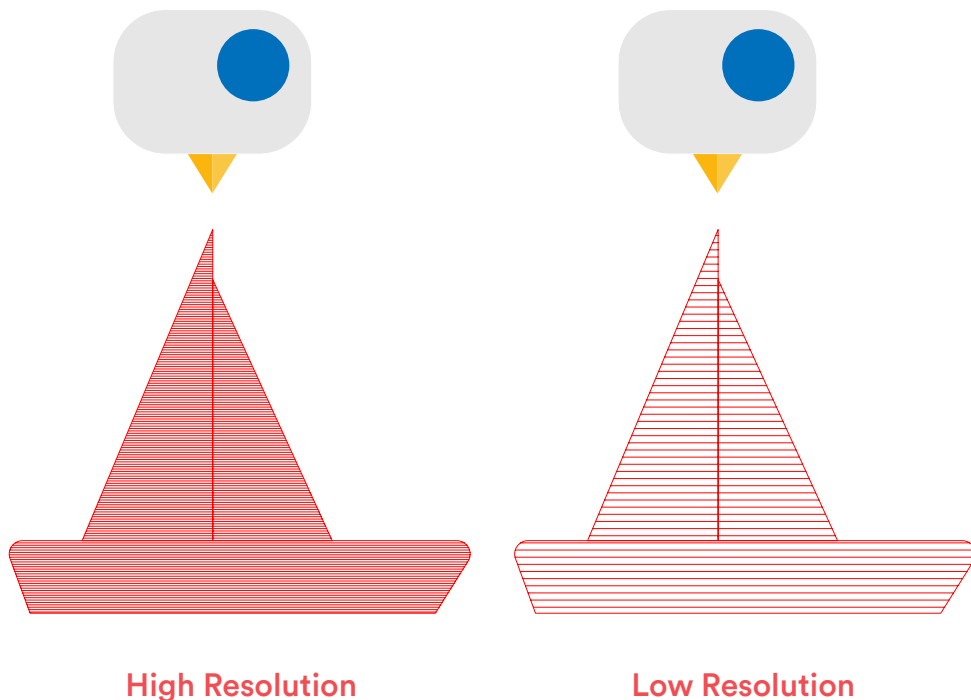
There is often some confusion in which bed adhesion method to use, if any. Our advice is to try all options and see what works best for the models you are printing.

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Resolution

Preparing Files for
3D Printing

Resolution in 3D printing terms usually refers to the layer height. Generally, the smaller the layer height, the better the surface quality. However using very small layer heights can add a considerable amount of time to the printing process. When printing in the classroom you must balance print quality with time.



High resolution prints generally have layer heights between 0.02mm and 0.1mm. An important thing to note is that resolution is not the only factor that affects surface quality. Other factors that affect surface quality include print speed, nozzle temperature, x/y accuracy of your printer and the physical design of your model.

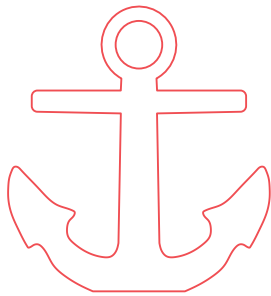
Low resolution prints can have layer heights around 0.3mm. These types of prints are especially good for the classroom if you have a large amount of students requiring 3D prints because the print time can be dramatically reduced. An important thing to mention is that when printing with thick layers, the print speed may need to be reduced.

027

Infill

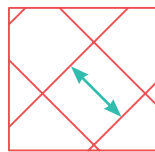
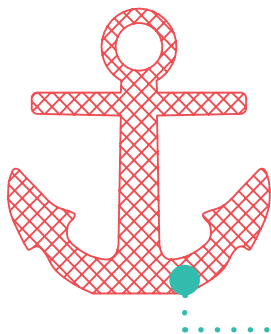
Preparing Files for
3D Printing

Another important setting to explore is infill. Infill refers to the structure inside a model. Most 3D prints are not solid because they have a grid-type pattern printed inside to save time and filament. You can easily adjust the density of your models within slicing software. Below are some plan views (looking straight down) showing different infill scenarios for a model of an anchor.



Hollow

Models can be printed completely hollow with only an outer shell. Many models can print hollow without it affecting surface quality but models with large top surfaces may struggle because the printer won't have material/infill to print on top of.



Regular

Most models are printed with infill lines around 4-6mm apart or around 20% density.

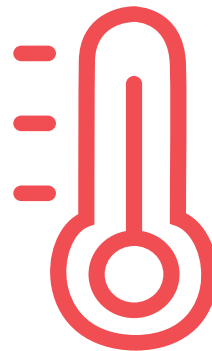


Solid

Solid models aren't very common in the classroom unless it is a functional requirement. Printing solid objects uses much more material and can take much more time but it can be a great way to teach about density and mass!

The print speed and temperature you should choose are dependent on several factors including material type, surface quality desired and time constraints.

Below are some general tips on making your selection.



Print Speed

- Choosing fast print speeds will affect surface quality so if you are looking to create smooth finishes, opt for a slow print speed. A slow print speed for printing PLA is generally around 30-50mm/s.

- If opting for a fast print speed, be careful not to push the printer too much because this will cause underextrusion. This will show up and holes in your print and happens because the printer cannot extrude enough filament in time.

Temperature

- For better surface quality you want to opt for a low temperature but going too low will also give you underextrusion. Experiment to find the right temperature for your printer and material.

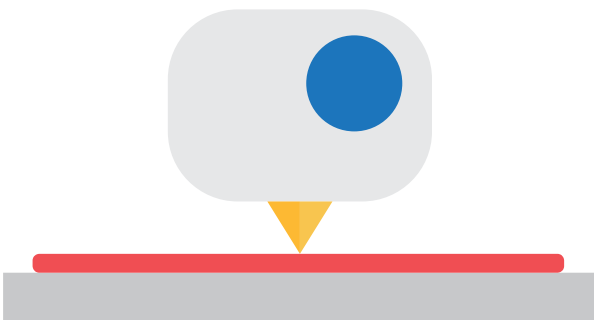
- When printing with fast print speeds, temperature may need to be increased in order to reduce underextrusion effects. Again experimentation is the best way to figure out the best settings for your printer and material.

029

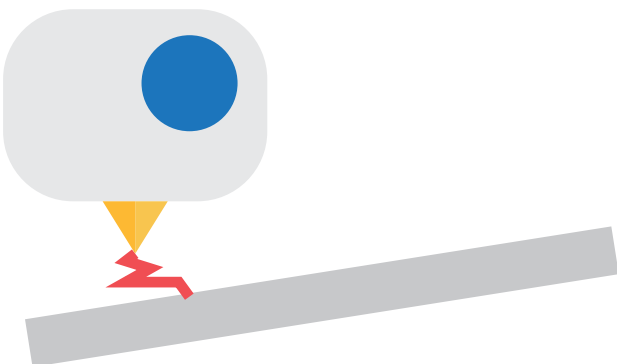
Calibration

Preparing Files for
3D Printing

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 is not 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 take a look at 2 scenarios to explain why calibration is so important.



1. In this scenario the print bed is completely level. 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.



2. If the print bed is not level, 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.

4.

3D Printing Tips for the Classroom

In this chapter we'll be giving you some essential tips for 3D printing in the classroom. These include considerations such as time and cost management.



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3D Printing Tips
for the Classroom

Calculating Filament Costs

Most slicing software packages provide you with printing information such as the amount of material the print will use. This means you can work out the approximate cost of a print. The first thing to do is to calculate the cost of 1g of filament. You can do this by following the below questions.

What is the weight of one of your filament reels in grams?

What is the cost of one of your filament reels?

The calculation to work out the cost of 1 gram of filament is:

cost of filament reel / weight of filament reel

e.g. If your filament costs \$35 and the weight of filament is 750g, the cost of 1g of filament = \$0.05.

What is your cost of 1g of filament?

Now that you have your cost of 1g of filament, simply slice some models to find out the grams of material each model will use. Then the material usage in grams by the cost of 1g of filament to work out the approximate cost of each model. By experimenting with various model sizes and infill settings, you will be able to get a good indication of your material costs in the classroom.

031

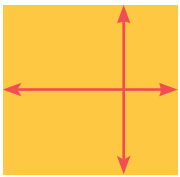
3D Printing Tips
for the Classroom

Classroom Tips for Costing

1. Keep a Log

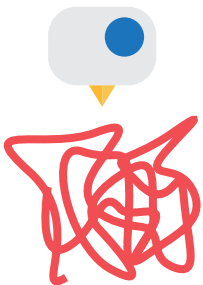


It can be very helpful to keep a simple log of the amount of filament being used over a period of time. Take note of how the amount changes over time - is it increasing as more students gain access to the 3D printers? This will help you when budgeting for materials. In addition to the amount of filament, keep note of what specific type and colour of filament is being used. You may find that certain colours are more popular than others and you should therefore place your orders accordingly.



2. Set Design Criteria

Some students may be tempted to print their designs as big as possible! It's always good to set some design criteria, for example tell you students that their designs must fit within the dimensions 50x50x50mm. This also gets them thinking about real-world applications, where most designs have a set brief to follow.



3. Budget for Failed Prints

Although 3D printing has come a very long way in recent years, you will still come across failed prints. This isn't always to do with the hardware or materials - in fact the majority of the time it may be that designs haven't been optimised for 3D printing. An example of this is if a student creates a design that has holes in the model, resulting in a failed print. When budgeting for materials, keep this in mind and include failed prints in your log.



4. Group Work

In addition to individual projects, encourage students to work in groups. This again relates to real-world applications because it is rare that architects or engineers will work on projects alone. By working in groups it reduces the amount of printing, but still engages each student in the design process.

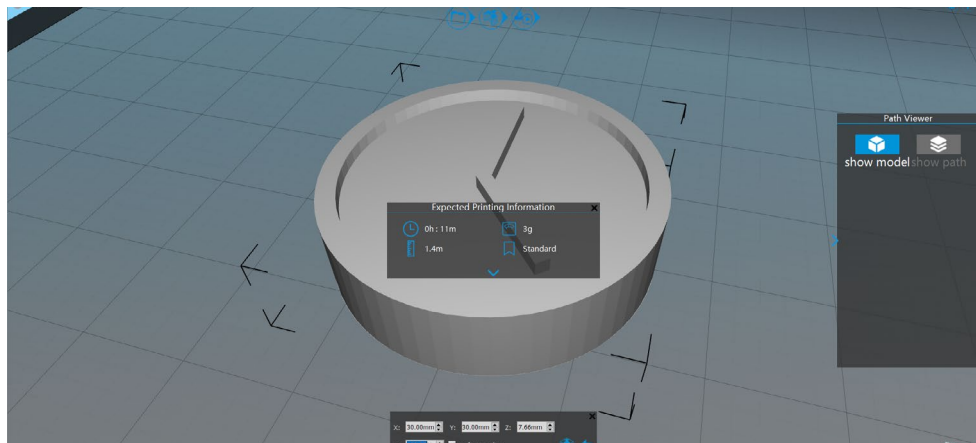
032

3D Printing Tips
for the Classroom

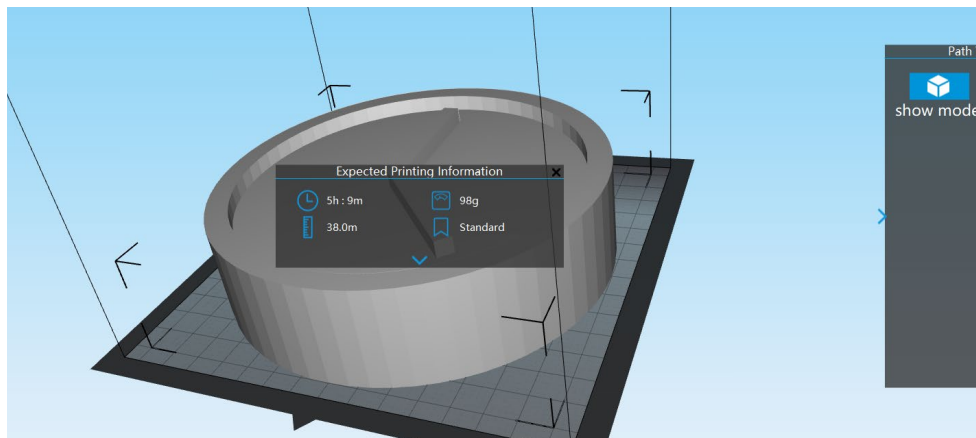
Managing Print Time

Similarly to the costing exercise, you can also experiment with printing time. Try slicing various sized models to see how the print time is affected. Below is an example where we sliced the same model twice at different sizes. Model 1 has an estimated print time of 11 minutes whereas model 2 has a print time of 5 hours! A good classroom tip to remember is that it is not always essential for every student to have a large print for themselves. Consider group work or competitions where students vote for which design is 3D printed. Another good tip is to make use of the print bed and load as many designs onto the bed as possible within your slicing software.

Model 1: 30×30×8mm - Print Time: 11 minutes



Model 2: 145×145×37mm - Print Time: 5 hours



General Classroom Tips

Here are some final tips to keep in mind when 3D printing in the classroom:



1. Let students handle 3D printers

There's no better way to learn about 3D printing than to get hands-on. This especially applies to students! So make sure they have access to the printers - let them tinker and fix technical problems themselves.



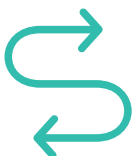
2. Work together with students

Don't be afraid to admit to your students that you don't know everything about 3D printing. Work together with them in solving problems and keep your lessons open ended. What we mean by this is that although lessons should have set criteria and learning outcomes – there is a world of opportunity beyond this if you allow students some freedom to explore.



3. Don't isolate 3D printing

In modern day industry, it is rare that 3D printing is used as a tool on its own. It compliments other forms of design and manufacturing, such as laser cutting, CNC machining and 3D scanning, to enhance the outcome. Keep this in mind when planning your lessons and integrate 3D printing with core curriculum topics.



4. Be flexible and open to change

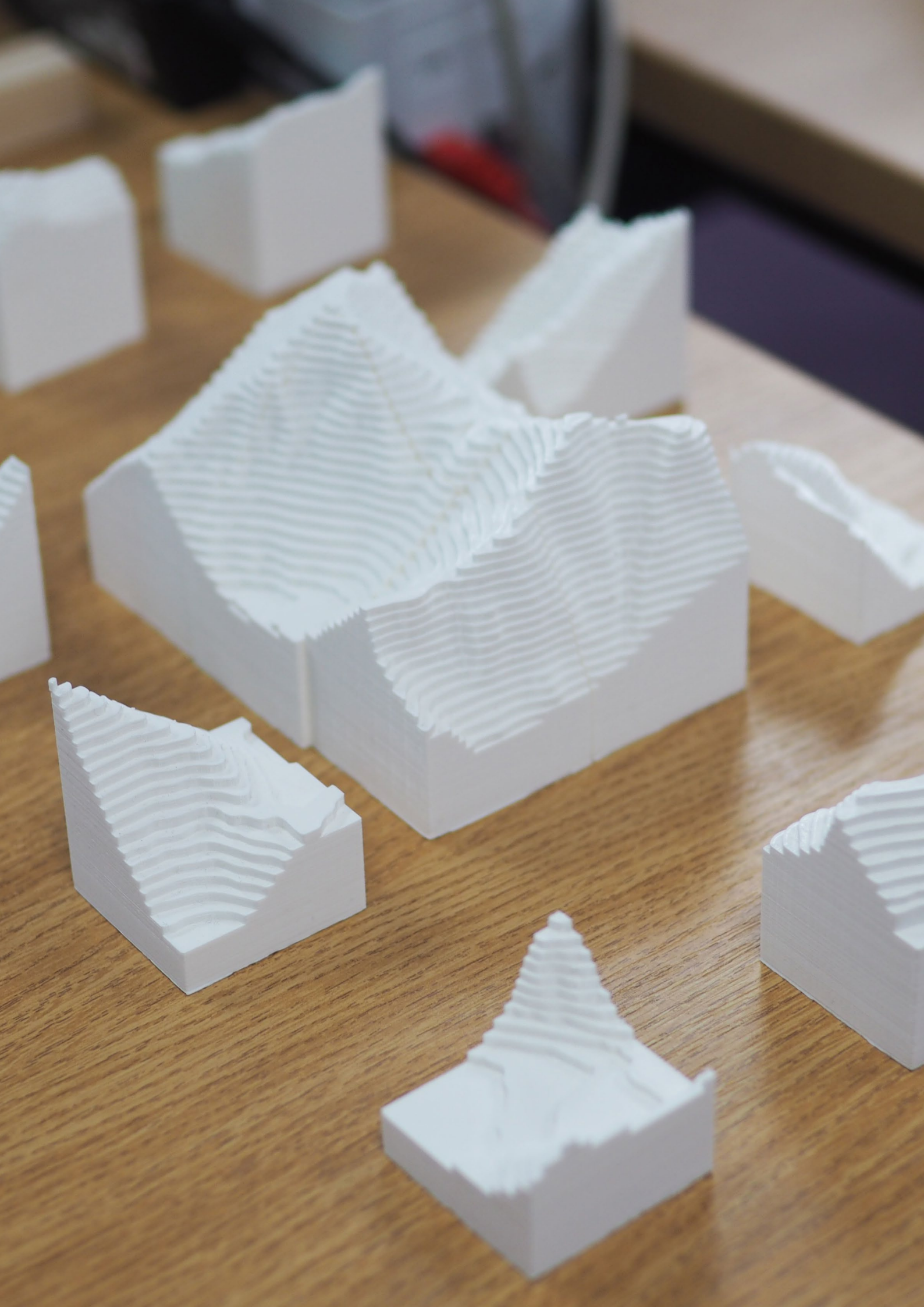
Something just as important as having a plan, is the need to be flexible and open to change. It is highly likely that the way you do things when you first begin your journey will be completely different to a year down the line. This is all part of the development process, so always try new techniques and keep an open mind.

5.

Integrating 3D Printing into the Curriculum

Whether you teach technology, computing, maths, science, history, geography or any other subject, we can assure you that 3D printing has a place in your classroom. In this chapter we'll take a look at some example 3D printing lessons that can be integrated into core topics. The examples shown are from PrintLab Classroom - a creative lesson plan portal for teachers. You can learn more about PrintLab Classroom at:

<https://classroom.weareprintlab.com/>



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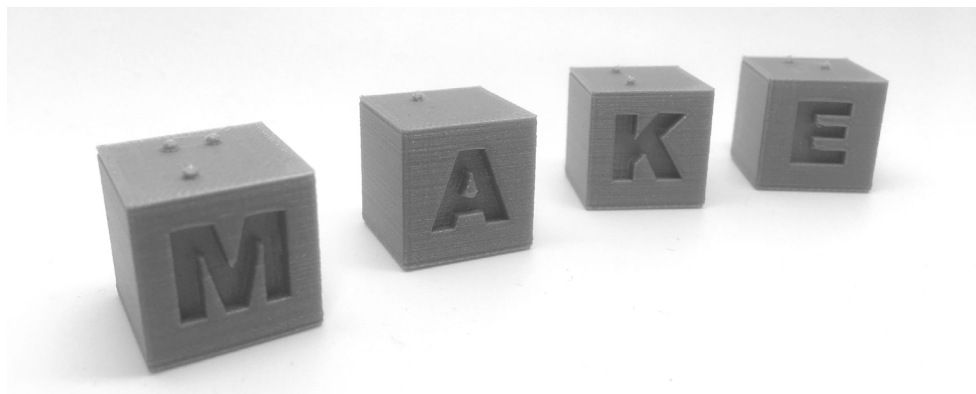
3D Printing Braille

Integrating 3D
Printing into the
Curriculum

In this 1 hour lesson students collaboratively design and 3D print their school name in braille. The lesson involves context about the written language braille along with mathematical calculations, CAD design and 3D printing. Each student is assigned a different letter of their school name to design in Tinkercad software and the braille blocks are 3D printed and placed together in a readable format.

English/Languages | Maths | Design Technology | Computing

Try this lesson for free here: <https://bit.ly/2IZUhoO>



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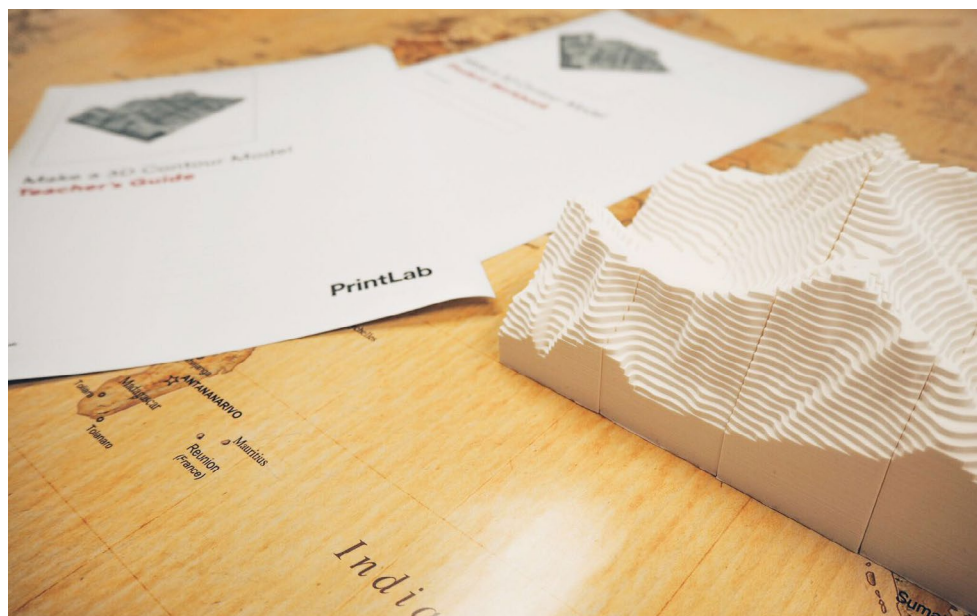
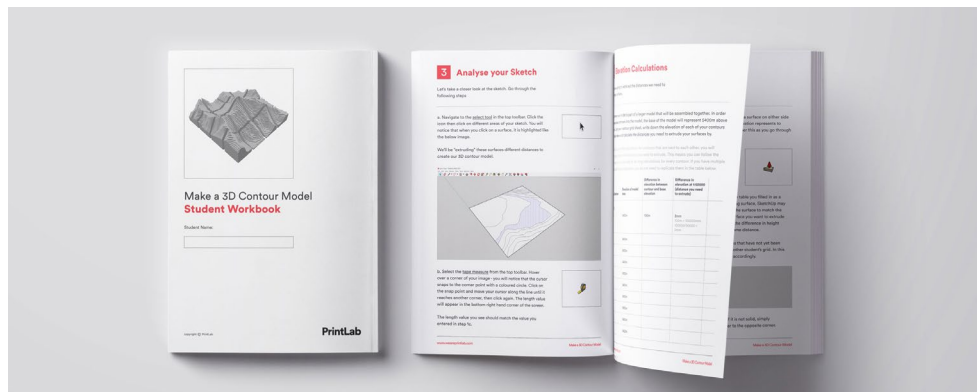
Integrating 3D
Printing into the
Curriculum

Make a 3D Contour Model

In this lesson students collaboratively design and 3D print a 1:50,000 scale model of Mount Everest and its surroundings. The lesson involves mathematical calculations along with CAD design tasks, mapping skills and 3D printing. Each student is assigned a separate part of the model to design in SketchUp software, which is 3D printed and assembled so that students can fully understand the topography of the world's highest mountain.

Geography | Maths | Design Technology | Computing

Watch the lesson video here: <https://bit.ly/2IZTGDA>



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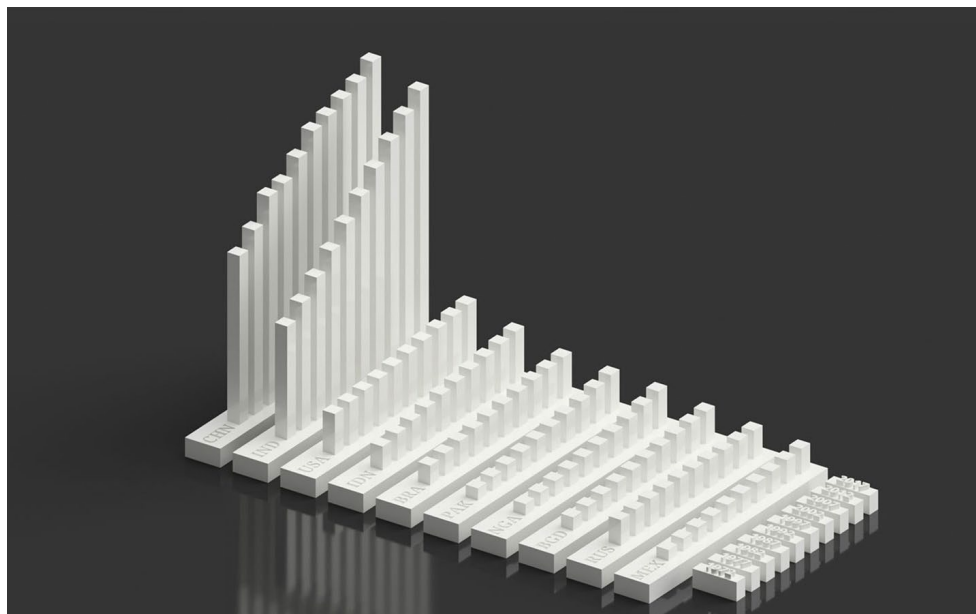
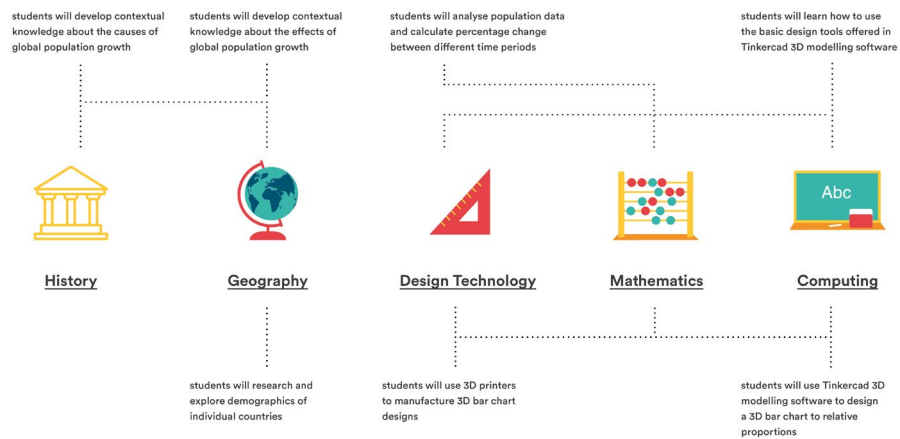
3D Population Graph

Integrating 3D Printing into the Curriculum

In this lesson students collaboratively design and 3D print bar charts showing the population growth of 10 countries from 1972 to 2017. The lesson is spread over 3 x 1 hour sessions and involves context about the causes and effects of global population growth along with mathematical calculations, CAD design, 3D printing and demographic research.

Maths | Geography | History | Design Technology | Computing

Watch the lesson video here: <https://bit.ly/2qAlwOO>



037

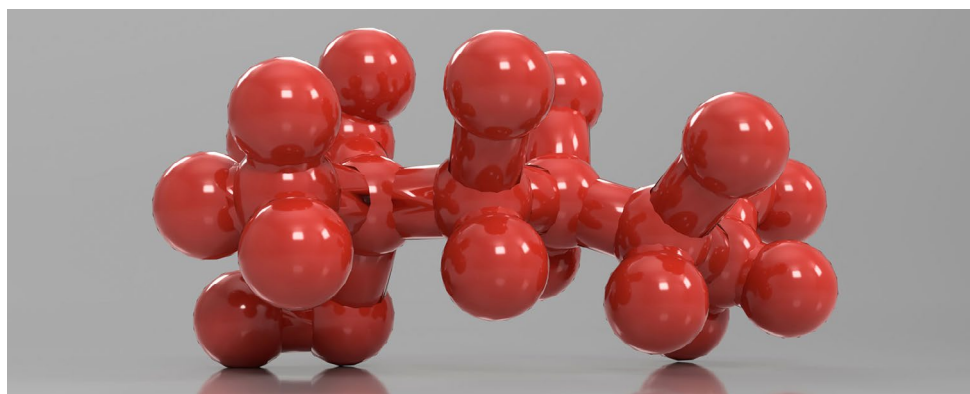
Integrating 3D
Printing into the
Curriculum

3D Printing Molecules

In this 3 lesson project, students learn how to design, edit and 3D print chemical structures using free software. The project involves an introduction to atoms and molecules before students split up into teams. Each team will be allocated a different molecule to research before 3D modelling and 3D printing the chemical structure. By 3D printing and having a tangible object, students can better visualise and understand the molecular world. In the final lesson of the project, each group will present their 3D printed model along with their research.

Chemistry | Biology | Physics | Computing

Watch the lesson video here: <https://bit.ly/2JPidN1>



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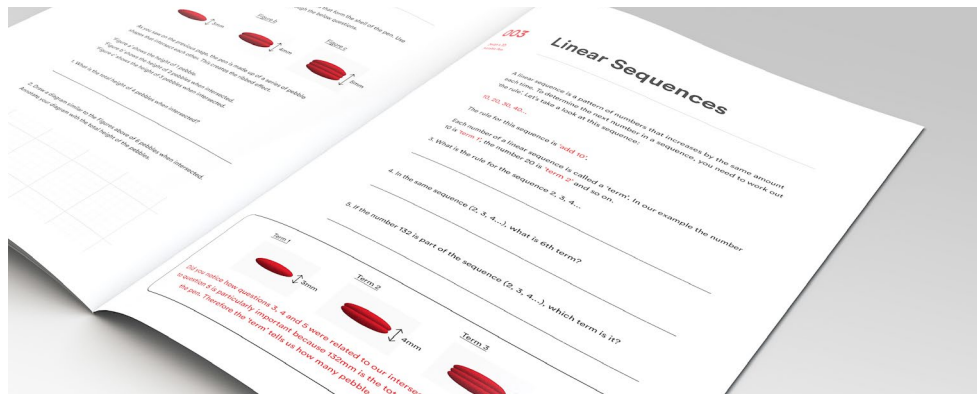
Integrating 3D
Printing into the
Curriculum

Design a 3D Printable Pen

In this lesson, students design and 3D print a functional pen. The lesson begins with a series of mathematical calculations on linear sequences. The calculations help students determine the measurements of the pen, which is designed in Tinkercad in the main part of the lesson. Finally, one of the pens is 3D printed and once complete, a Bic biro cartridge slots into the centre to make it functional.

Maths | Art & Design | Design Technology | Computing

Watch the lesson video here: <https://bit.ly/2H6c94P>



039

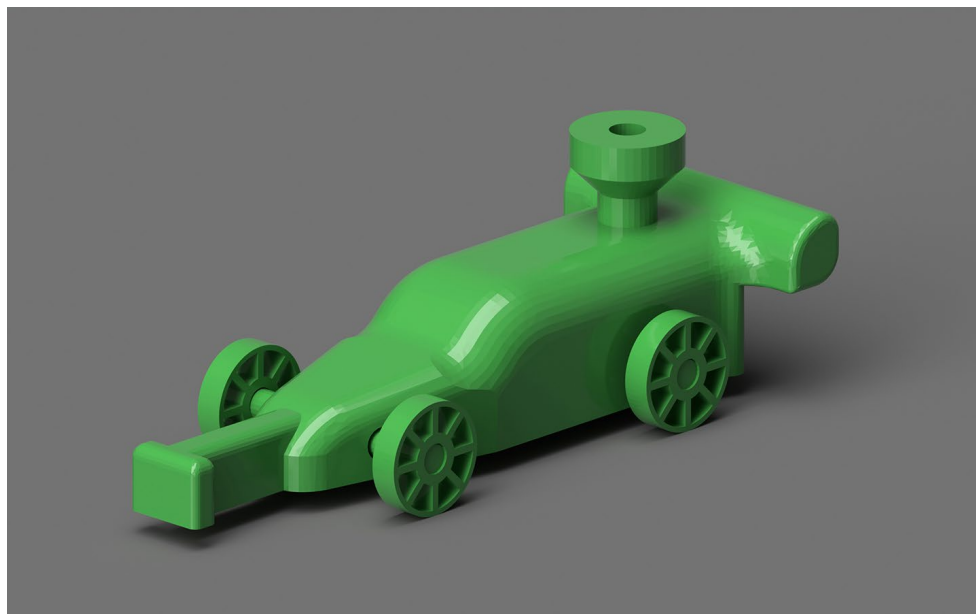
Integrating 3D
Printing into the
Curriculum

Balloon Powered Dragster

In this project, students will begin by learning about forces, motion and Newton's Third Law. Using this knowledge, students will embark on a creative journey to design and 3D print their own functional, balloon powered dragster! Their aim is to create a vehicle that can travel as far as possible in a straight line and in the final lesson, they will compete against each other using their own unique dragsters.

Physics | Maths | Design Technology | Computing

Watch the lesson video here: <https://bit.ly/2H1E95D>



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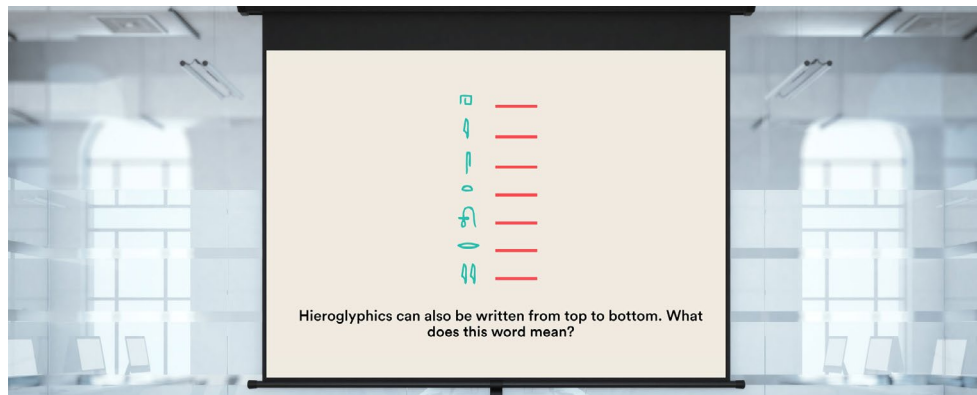
Integrating 3D
Printing into the
Curriculum

Make an Egyptian Obelisk

In this lesson, students design and 3D print a personalised Egyptian obelisk. The lesson begins with a presentation and discussion session about hieroglyphics and obelisk monuments. Following the presentation, students will be split up into teams and given a 3D printed obelisk model, prepared by the teacher prior to the lesson. The mission for the teams is to decipher the hieroglyphic word and research its meaning and relevance to Ancient Egypt. The lesson ends with students presenting their findings. In the second lesson, students will use a tutorial video to design and 3D print their own personalised obelisk!

History | Religious Education | Art & Design | Design Technology

Watch the lesson video here: <https://bit.ly/2EQ5pID>



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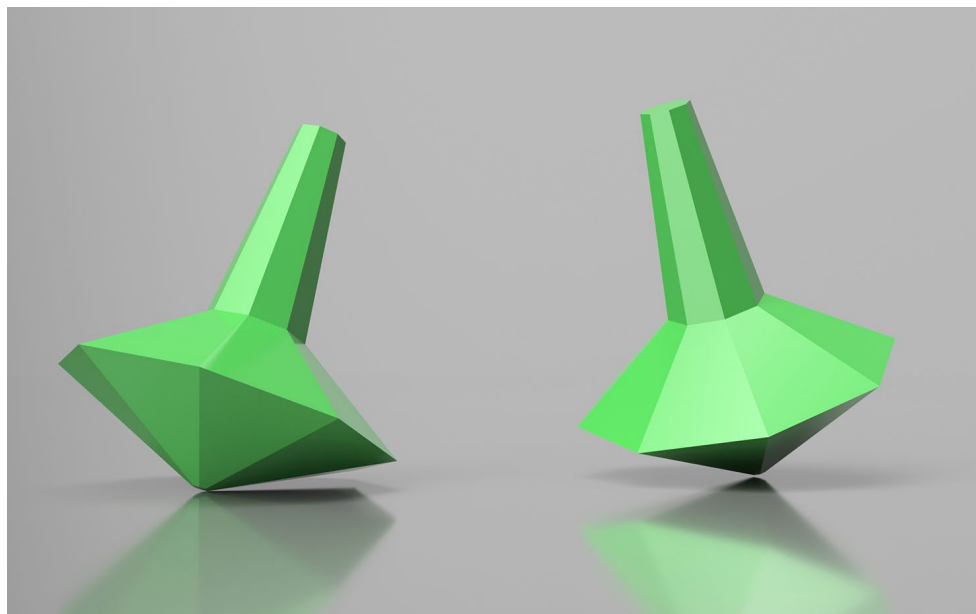
Integrating 3D
Printing into the
Curriculum

Design your own Spinning Top

In this 2-part lesson, students design and 3D print their own unique spinning top. During the lesson they will experiment with demonstration models and make design decisions on how they intend to improve the design and aesthetics of the demonstration models. In the main part of the lesson, students will follow an instructional video to design a spinning top. Using the skills learnt in the tutorial, they go on to design their own unique spinning top, which will be used in the class competition in lesson 2!

Physics | Maths | Design Technology | Computing | Art & Design

Watch the lesson video here: <https://bit.ly/2H1E95D>



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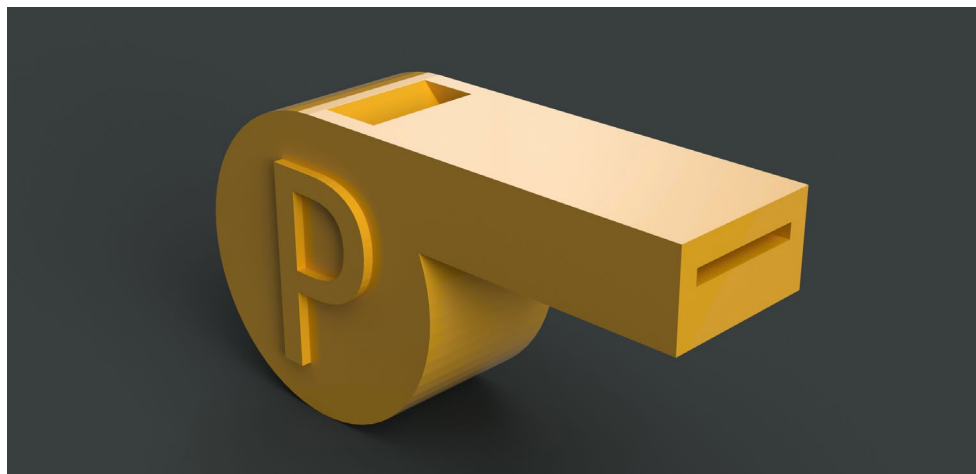
Integrating 3D
Printing into the
Curriculum

Design your own Whistle

In this 4 lesson project, students embark on a design journey to create their own functional 3D printed whistle. Lesson 1 begins with a presentation and discussion about sound waves, frequency and amplitude. The class will then go through a 3D modelling tutorial in Tinkercad to design and 3D print a whistle. The design tutorial will give students the necessary CAD skills to create their own unique whistle designs in the next part of the project. In lessons 2-3, students use research and sketching methods before they 3D model and 3D print their own whistle. In the final lesson, students will test their whistles, analyse their designs and consider any improvements.

Music | Physics | Maths | Design Technology | Computing

Watch the lesson video here: <https://bit.ly/2EQbRZZ>



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3D Printing Solutions

Integrating 3D
Printing into the
Curriculum

It has been our mission from day 1 to build a 3D printing ecosystem specifically for education and we are excited to support more teachers in their 3D printing journey! If you're looking to introduce 3D printing into the classroom, we have a range of 3D printing bundles that start as little as \$835 (USD).

Learn more about our solutions at www.weareprintlab.com



Let's inspire the next generation, together

We hope you found the information provided in this guide useful and please feel free to get in touch with us!

hello@weareprintlab.com

www.weareprintlab.com
