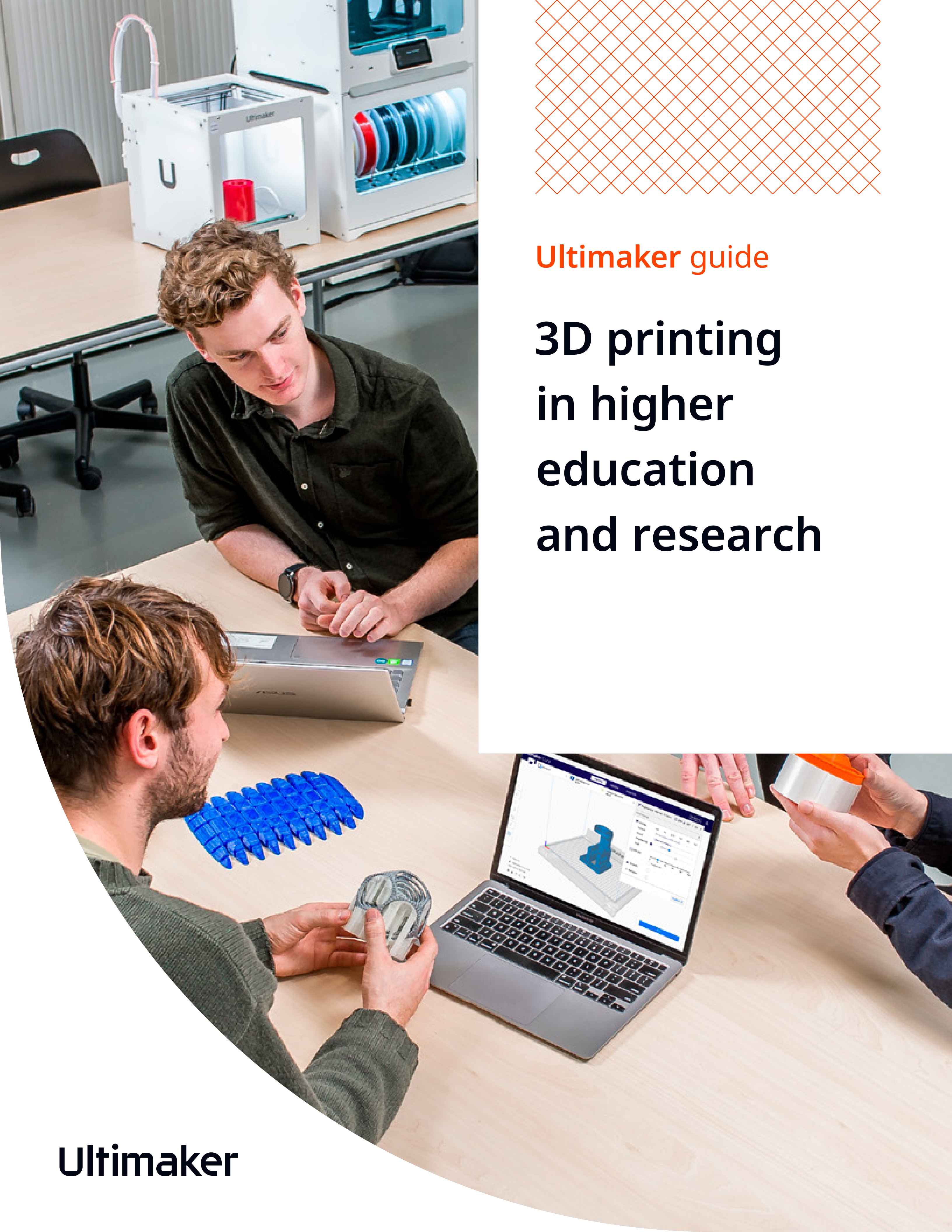

Ultimaker guide

3D printing in higher education and research

Ultimaker

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Introduction

In a fast-changing and complex world, equipping young people with the right skills for the future is not only more important than ever – it’s more challenging than ever.

The challenges for educators are dual.

The first is not new. Students need the right skills to succeed in the world they will graduate into. What is new is the pace of change in this world of work. Emerging technologies and digital transformation by businesses mean students in STEM subjects must be equipped with a wide range of modern, applicable skills. And that curricula must be able to change and adapt at short notice as trends emerge.

The other challenge is how to educate students in an education landscape changed forever by the COVID-19 pandemic. New health and safety considerations, budget pressures, and the combination of remote and in-person learning all remain relevant even as we move into a “post-pandemic” world.

Drawing on insights from educators worldwide, our own 3D printing experts, and data from research, we developed this guide to help educators navigate this uncertainty and ensure students can succeed in a digital future.

Keep reading to understand how 3D printing can be integrated into an academic or research institution, what sort of projects can be 3D printed, and see examples of success.

Why 3D printing?

3D printing is now an established technology in many industries, used primarily for prototyping designs and manufacturing end-use parts.

Teaching STEM students to understand how 3D printing technology (also known as additive manufacturing) works and apply it practically is going to be crucial to preparing them for the workforce.

In the early days of 3D printing, the technology was seen only as a rapid prototyping tool for designers. Now, industrial applications are so varied that 3D printing is used across the following industries:

- Aerospace
- Architecture and construction
- Art, fashion, and jewelry
- Automotive
- Biomedical science
- Defense
- Education
- Healthcare
- Industrial and product design
- Manufacturing and packaging

And within each industry, the number of job roles that can require 3D printing knowledge now includes:

- CAD designer
- Educator
- Operator / technician
- Purchaser / innovation manager
- Researcher

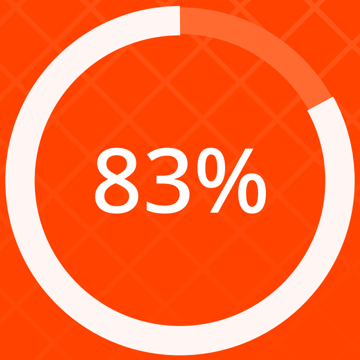
With students looking for the edge in a competitive jobs market, 3D printing can help to attract students to your institution, inspire their learning and projects, and help them develop the lasting skills needed for all these career paths.

By choosing desktop 3D printers that are compatible with a wide range of software and other tools, 3D printing can be easily adopted to complement a curriculum. 3D printing works alongside other specialist learning tools you may already have, such as CAD software, CNC and laser cutting,

But what does successfully adopting 3D printing within your institution look like? How many 3D printers are needed? What can and can't they be used for? How do you set up a 3D printing lab?

In the following sections, we'll answer these questions using knowledge from our extensive research together with academic institutions worldwide – sharing effective applications, environments, and workflows which ensure great outcomes for both educators and students.

The potential of 3D printing in education



of educators say 3D printing can offer extensive benefits in bringing new concepts and design ideas to life

of educators believe 3D printing will revolutionize their industry

of educators think 3D printing will have as much or more impact on their industry in future than other new technologies like cloud, AI or big data

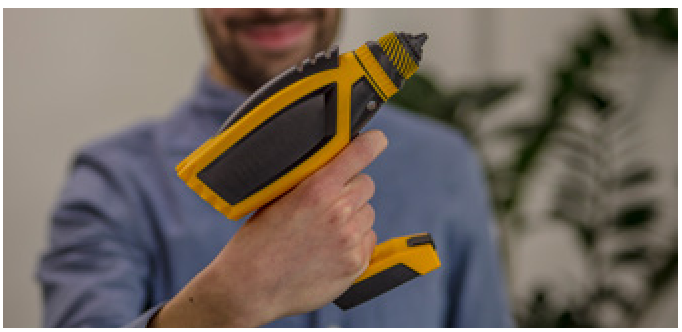
Source: Ultimaker 3D Printing Sentiment Index 2021

Uses of 3D printing

While the potential is clear, it's important to think about what you will use 3D printers for before making any investment decisions. In this section, we look at the applications 3D printing in higher education to help you understand how best to use the technology.

Concept models

Students can visualize concepts, either to show different directions in early design stages, or for one-off projects and demonstrations.



Visual prototypes

For students studying any design course, understanding iterative prototyping is essential. With a 3D printer, it's as easy as print, review, repeat...

End-use parts

Designing and producing usable components is valuable for engineering and research-focused disciplines. 3D printers can be used to make tools, molds, assemblies, and custom devices for experiments.

Individual student projects

Part of a university education is the freedom to think creatively, and experiment with projects. 3D printing can enable students while keeping you in control.

The basics of 3D printing

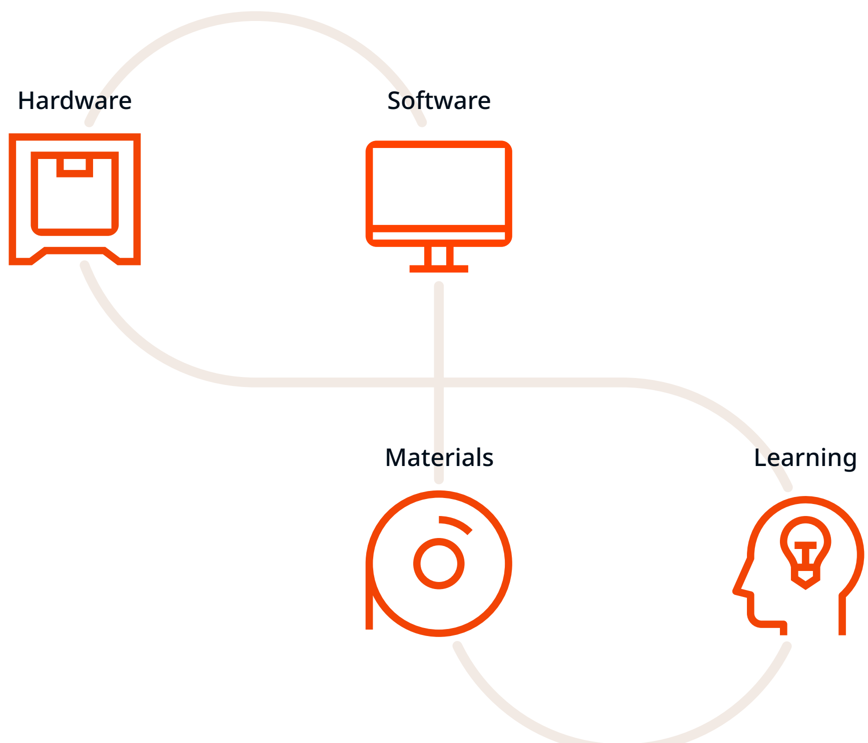
When choosing additive manufacturing technology for your organization, it's important to remember that a 3D printer does not exist in isolation. It needs the right materials to produce the parts you desire. Software is needed to prepare 3D prints, manage the process, and potentially integrate it into your existing tools and systems. And you should think about how operators will learn how to use the technology.

Don't worry if this sounds overwhelming. In this section, we'll walk you through everything you need to know.

It can be helpful to think of the 3D printer as a platform rather than only a piece of hardware. Just as a computer has several functions, inputs, outputs, and compatible accessories – a 3D printer is similar.

A 3D printing solution that provides everything you need in one platform will vastly speed up installation and onboarding.

The 3D printing platform



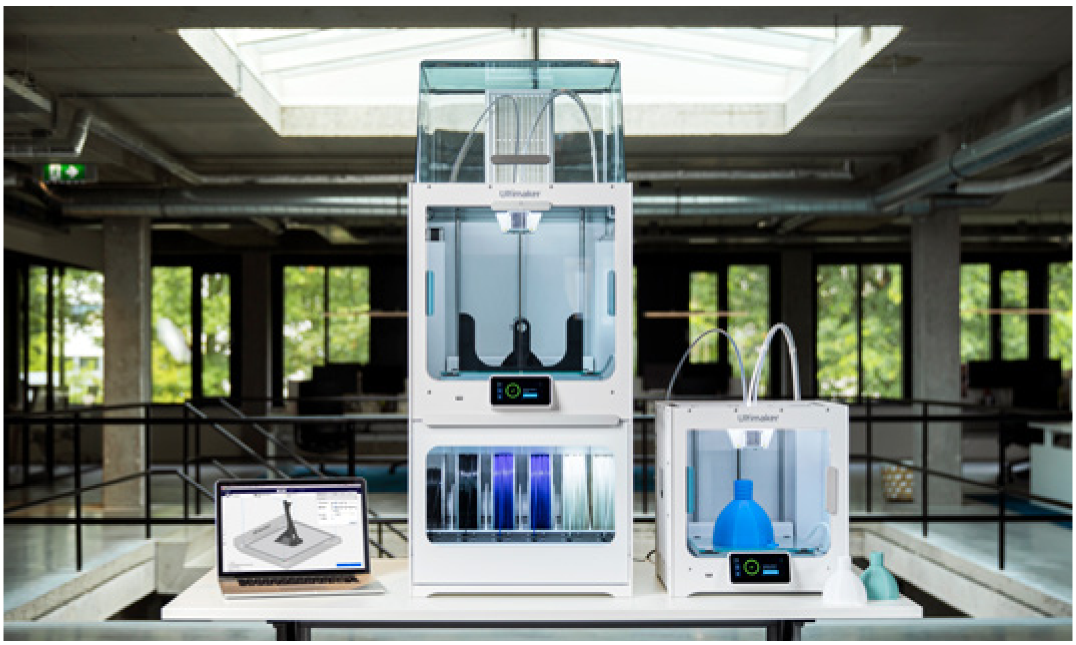
Hardware

Let's start with the 3D printer itself.

3D printers come in many shapes, sizes, and technology types. The most common 3D printer types work by extruding filament, fusing powder, or setting resin to create a solid final part. You can read more in our blog on this topic.

As for size, they range from large industrial units bigger than a person, down to the form of a small box that easily fits on a desk or workbench.

Ultimaker 3D printers are desktop machines that work with fused filament fabrication (FFF) technology. (That's one of the "extruding filament" types.)



Ultimaker desktop 3D printers

Most of this guide can be applied to all types of 3D printing. But to keep it from being exhaustively long, we will make it clear when a consideration is only relevant to FFF printing.

To make the right choices when investing in 3D printing hardware, we recommend focusing on the following considerations.

What are the specifications?

Tip! Faster prints are helpful in education to allow as many students as possible to use the printers, and for lessons and projects to run to planned timings.

Printer specifications will dictate the performance, capabilities, and limitations of your printer. Some of the key specifications to check include:

- **Build volume.** Sometimes also called build envelope or printable area, it is essentially the internal size of the printer within which a part or parts can be created. If you know you will need to print large objects, pay attention to this. Be aware that larger format printers cost more and take up more space.
- **Nozzle size (FFF only).** The diameter of the nozzle controls how much material is extruded at one time. Larger diameters give faster prints while smaller offer more fine detail. Ideally, look for a printer with multiple nozzle sizes you can swap in or out depending on the job.
- **Single or multiple extrusion (FFF only).** This tells you how many nozzles the printer has. Single extrusion can only print one material at a time. Dual extrusion, for example, has two nozzles and can therefore print two materials. This enables the creation multicolor prints or the combination of materials with different properties in one part.
- **Connectivity.** A bit like an office paper printer, you need to send a print job to a 3D printer. This can usually be done by an external memory device like USB stick, but look out for Wi-Fi and LAN connectivity options too that make it much easier to network and manage multiple printers.

Installing 3D printers

So, you've identified a printer with the right specs that can print the parts your students need. Now it's time to think about where to put it and other operational considerations for an education environment.

- **Quantity.** One 3D printer may be enough for a single research project, but it's unlikely to meet the needs of an entire faculty or department. Think about how many students will need to be 3D printing simultaneously and work out your capacity needs.
- **Placement.** Check the external dimensions of each printer and how it is accessed. Some 3D printers need access to the side or back of a machine, for example for material loading. Do you have an existing surface the printers can be placed on, or will you need to install a rack? Also consider access to power sockets. Printers require some consumables too, such as material and any other accessories you plan on using, so assign some space for these.
- **Environment.** As with any technology it is important to consider its impact on the indoor environment – particularly air quality and noise. Printer specs should include a maximum decibel level, but a simple rule is that an enclosed printer is quieter than one with an open frame. For air quality, we recommend checking your institution's health and safety requirements and consulting with the responsible personnel.

Tip! Many printers come with devices to filter out potentially harmful particles, such as the Ultimaker Air Manager. Ultimaker offers further information on air quality here.

Ultimaker 2+ Connect with Air Manager, which filters up to 95% of ultrafine particles

Maintenance and support

Tip! Ultimaker software provides a digital record of maintenance needs – scheduling upcoming tasks and allowing you to record when it was performed.

- **Regular tasks.** Ask your vendor about the maintenance needs of a printer before you buy. Ideally, these will be infrequent and can be performed with minimal need for tools or expertise.
- **Support.** In the event something goes wrong, you want to be covered. Check what warranty and customer service you get with a printer.

Materials

3D printers can produce parts using a wide range of polymers, as well as other materials (usually in a composite together with a polymer).

- **Commodity materials.** These include PLA and ABS, are commonly used for product development or model-making.
- **Engineering materials.** Materials such as PA, TPU, and PETG these are used for applications that could potentially better serve the functional requirements of mechanical applications and end-use products.
- **High-performance materials.** Including PEEK and PEI, these are best suited for applications that provide mechanical properties suitable to meet the highest requirements. These are typically not printable with desktop 3D printers and require more industrial solutions.
- **Composites.** These materials combine a polymer with fibers of another material, such as glass, carbon, or metal, to provide enhanced visual or mechanical properties. Composites often have abrasive effects on the internal mechanisms of a 3D printer, so always check compatibility.

Once you know your material needs, be sure to choose a printer that can support these. Material compatibility should be listed in the printer specs. Some printers are designed to give specialized results with only one or two materials, while others can print with almost any material.

Also check if the printer is compatible with proprietary materials only or also with materials made by third parties. Choosing a closed system can seriously limit a printer's flexibility and therefore usefulness, while an open system provides endless opportunities.

Software

There is a great variety of software tools to help educators make the most of 3D printing, both free and paid. For the purposes of this guide, we will focus on software that is directly involved in the 3D printing process.

- **Print preparation (or "slicing").** Software is needed to turn a CAD design file format into a 3D printable file. Typically, this involves turning a 3MF or STL model file into a G-Code, which can then be sent to the printer. This is done in "slicing" software, such as Ultimaker Cura. A slicer also lets you choose settings to determine the properties of the print: visual quality, print speed, internal density (or infill), scale, and more.
- **Printer management.** If your printer is network enabled, this means you connect it and any others to printer management software. Features vary between software providers, but the overall advantage is that you can control the printers from one place, and with more advanced controls that is possible just printing with USB sticks. Ultimaker Digital Factory, for example, offers remote printing via the cloud, user management to control who can access printers, direct support, and increased security.
- **Software integrations.** Software is the hub of your 3D printing platform. You can leverage software to integrate it into your existing workflows or add more capabilities. In the Ultimaker Marketplace, for example, you will find software plugins to create an easier workflow with leading CAD and PLM software found in today's workplace, as well as pre-configured print profiles for hundreds of third-party materials.

Tip! Cloud-based remote printing adds additional resilience in the face of COVID-19, enabling students to 3D print without having to be in the same location as the printer. In case of particularly severe restrictions, printed parts can be held centrally by the department and either collected by or dis-patched to students.

Learning

Lack of 3D printing knowledge or skills can hold back institutions who may otherwise want to adopt 3D printing. Technicians may need retraining to manage 3D printers, or educators may worry about students' competence with the technology.

With an Ultimaker 3D printer, all your operator or students need is a quick 30-minute introduction. And it's included as an e-learning module with every purchase.

And with the Ultimaker 3D Printing Academy, get access to hours of extensive e-learning courses about our products and relevant industry applications, all created by 3D printing experts. Plus, specific learning tracks for lab technicians or students provide tailored knowledge for all your 3D printer users.

How to set up and manage a 3D printing lab

Now we know the key concepts and considerations relating to 3D printing in higher education, it’s time to put this into action.

But depending on the needs of your students, how you set up and manage your 3D printing space will differ. From our extensive research, we’ve identified three main types of 3D printing “labs” deployed by education institutions already using 3D printing:

- **General access lab.** A dedicated “makerspace” open to students to use for both personal and academic projects. Often shared between departments or faculties, it enables the application of a broad range of skills and academic disciplines.
- **Teaching lab.** Useful for design and technology courses, this model puts the 3D printers within the teaching environment, such as a workshop or classroom. It enables specific curriculum or project outcomes for students in close collaboration with teachers
- **Application lab.** Primarily for final-year projects, this lab offers 3D printing and other fabrication technologies for students to choose and apply as they need. Typically for engineering and industrial design courses, it should meet the needs of demanding projects and give professional quality results.

Let’s look at each environment in more detail to understand how they work and how to equip the lab that best meets your needs.

General access lab

Priorities	High capacity, high uptime, low maintenance
Application types	Individual student projects
Number of users	Large (20+)
Equipment needs	• A large number of lower cost, single extrusion "workhorse" 3D printers • A small number of dual extrusion 3D printers, for the occasional more complex part • Primarily PLA material, in a wide variety of colors to enable creative projects • Slicing software, plus printer management software with remote, cloud 3D printing capabilities • Highly recommended to choose a software plan with user access management features, such as Ultimaker Essentials • E-learning courses to help onboard lab users
Workflow management	Once set up, general access labs can usually be managed effectively with minimal input from the faculty. Typically, a lab assistant will be responsible for maintaining the printers and can act as an approval step to check students' files are correctly sliced before printing. In some cases, this is also done by (or with help from) engaged volunteers from within the student community.

Teaching lab

Priorities	Low maintenance, low noise levels
Application types	Concept models, visual prototypes
Number of users	Medium (10-20)
Equipment needs	• A small number of dual extrusion 3D printers with good reliability • PLA and PVA materials for the creation of more complex models • Choose more advanced materials to meet your curriculum needs • Slicing software, plus printer management software with remote, cloud 3D printing capabilities • Highly recommended to choose a software plan with user access management features, such as Ultimaker Essentials • E-learning courses to help onboard lab users
Workflow management	A lab assistant, lab manager, or another member of teaching staff consults with students about their projects to determine the appropriate production technology. If this is 3D printing, once the student's design is ready, this staff member checks files are correctly sliced before printing. Where relevant, a feedback loop to review the 3D printing experience will help the student learn design for manufacturing skills.

Application lab

Priorities	Extensive material range, high-quality output
Application types	Concept models, visual prototypes, end-use parts
Number of users	Small (up to 5)
Equipment needs	• A handful of high-spec, dual extrusion 3D printers • A wide variety of engineering materials for student-designed parts with demanding mechanical, thermal, and other properties • Slicing software, plus a platform that can add integrations with industry-standard software and materials, such as Ultimaker Marketplace • E-learning courses to help onboard lab users
Workflow management	In this learning environment, students should be able to act more independently having already acquired the design for additive manufacturing knowledge to use the technology successfully.

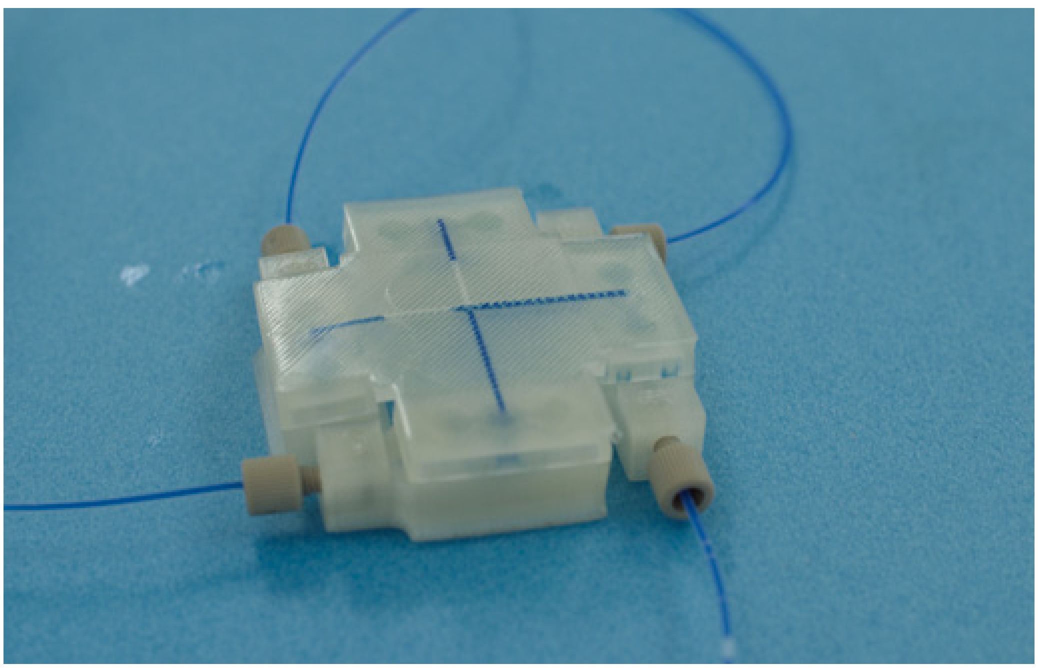
Education success stories

Cardiff University

Researchers at Cardiff University use 3D printing to create small microfluidic devices that move small volumes of fluid and are used in various areas of research. 3D printing makes it possible to share the devices with other researchers, making the study of microfluidics more accessible to a wider audience. The 3D printed devices offer a cost-effective alternative to the traditional ones, which are expensive and require specialized skills and equipment.

Using their Ultimakers, researchers at Cardiff University now 3D print the microfluidic devices they use in their studies. The 3D printed devices are based on a modular system that consists of standard building blocks that are assembled together.

3D printing gives rise to significant cost savings over the traditional methods and allows for rapid iterations on the design of the microfluidic devices. Since the designs can easily be shared with researchers in different locations, microfluidics research becomes accessible to other researchers as well.



Inholland University

Students at Inholland University of Applied Sciences use 3D printing to design and build rockets as part of their course in aviation technology. Many aspects come into play – aerodynamics, weight and strength all need to be taken into account in the build. After successfully launching two rockets, each with 3D printed parts and composites, the students built a rocket that is entirely 3D printed.

3D printing is an emerging technology, and by the time the students hit the labor market in approximately 4 years from now, the 3D printing scene will have changed again. It is therefore important that schools and universities show the students that there exist alternative means of production. Check out the comprehensive lesson plan, which can be used to introduce 3D printing at your own university. The accompanying STL files can be downloaded here.

Best-in-class technology for students

Empower students to become the workforce of the future with a flexible, easy-to-use 3D printing system. Learn more at ultimaker.com

Discover 3D printing in education

Talk to an expert

About Ultimaker

Since 2011, Ultimaker has built an open and easy-to-use solution of 3D printers, software, and materials that enables professional designers and engineers to innovate every day. Today, Ultimaker is the market leader in desktop 3D printing. From offices in the Netherlands, New York, Boston, and Singapore – plus production facilities in Europe and the US – its global team of over 400 employees work together to accelerate the world's transition to local, digital manufacturing.

ultimaker.com

General inquiries: info@ultimaker.com

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