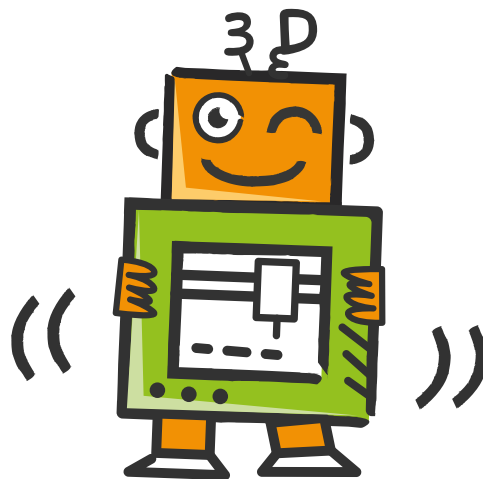
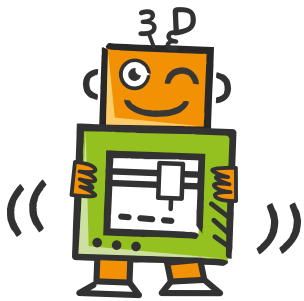

EMPOWER3D

3D Printing and Modeling for Schools



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Introduction to 3D printing

In today's age of technology, when 3D printing and digital manufacturing are becoming a common part of industry and households, it is important to prepare children for a world in which these skills will be an integral part of their everyday lives. This teaching methodology is aimed at primary school teachers who want to integrate 3D printing, basic modelling and related technologies into their teaching and introduce them to their pupils in a fun and practical way. Our goal is to provide you with basic orientation, inspiration, tangible examples of activities and tools to make 3D printing accessible to even the youngest learners, while fostering their creativity, technical thinking and collaborative skills.

The use of 3D printing at primary school

In the primary school, working with 3D printing can be motivating because it allows

children to create something tangible that they can take in their hands, show to their parents or use in their play. This experience can be an introduction to a world of technology and design that may otherwise be difficult for them to grasp.

Visual and tactile aids

At an early age, children learn mainly through experiences and specific objects that they can explore with all their senses. Thanks to 3D printing, we as teachers can prepare teaching aids that are precisely adapted to the learning process and age of the pupils. For example, in mathematics, different geometric shapes can be printed to help children better understand the differences between objects and their connections. Similarly, letters and numbers can be printed out for the first practice of reading and counting, or models of animals and plants for science.

Spatial models are ideal for young children with a need for visual learning, helping them to make deeper connections to the curriculum content. For visually impaired children in the primary level, teachers can easily prepare special tactile aids that would otherwise be very expensive or hard to find. For example, embossed maps or simple tactile elements allow them to engage fully in the classroom.



No need to worry about 3D printing even at the primary school level (source: <https://teachyourkidscode.com/>)

Development of creativity and fine motor skills

In the primary school it is important to develop fine motor skills and hand coordination, which is often done through drawing, cutting and various art activities. 3D printing can help with this development very well. Children can learn simple modelling programs where they draw their own designs, which they then print with the teacher. Creating designs helps them

develop their visual imagination and encourages logical thinking, while their final product motivates them to see the result of their efforts. As a result, children learn not only to create, but also to plan the steps and consider how to improve their design.

For children, this process can be very playful - they can design their own ornaments, small toys or even pencil boxes or other everyday trinkets, but personalised by themselves. In this way, they learn that technology doesn't have to be just for tech-savvy individuals, but also for creative ideas that they can implement. In addition to developing their creativity through 3D printing, children are also working on improving their patience and accuracy, which are valuable qualities not only for future school success, but also for life.

Promoting collaboration and teamwork

3D printing is also a great tool for promoting collaboration in the classroom. Children can work together on simple projects - for example, designing and printing different parts of a model town, animal farm or planetary system, with each team member contributing one part. Working on a collaborative project promotes communication skills, teaches children respect for their classmates and reinforces

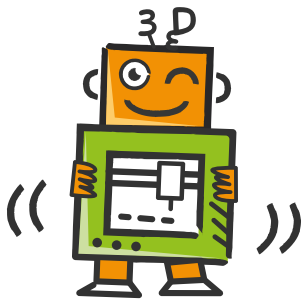
their responsibility for the outcome of the whole team.

This way of working is also very useful for inclusive classrooms, where children with different abilities can work together to contribute to the final project according to their abilities. 3D printing can be a great tool for them to engage in a collaborative activity and learn from each other without feeling a difference in skills.

Entertainment activities and games

In the first grade, 3D printing can also be used for a variety of fun activities and games that combine fun with learning. For

example, for geography lessons, teachers can use 3D printing to create puzzles with a map of their country or other countries that they can then put together. Similarly, interactive jigsaw puzzles can be made on different topics such as the human body, animals or, for example, the decomposition of numbers.



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3D printing and 3D graphics in the fields of human activity

Filament 3D printers are becoming increasingly popular in households today, mainly because their price is coming down and they are more affordable than before. Users can get a printer without having to invest a lot of money. As a result, 3D printing is also becoming more and more popular in schools and various organizations where printers can be used for interesting projects.

But it is not just about printing plastic objects. In addition to traditional 3D printers for plastic, there are also special 3D printers that can work with metal, biological materials or other special materials. However, these printers are still very expensive and are mainly found in research institutions and companies focused on specific fields. Still, it is interesting to be informed about them in order to have an idea of where 3D printing is being applied today and what possibilities it has.

In schools, we mainly encounter filament printers that print from plastic and can be a great tool for teaching creativity, technical skills or working with new technologies.

Prototyping

3D printing has been used for prototyping since the 1980s - allowing companies to quickly and cheaply test the visual appearance and functionality of products before mass production begins. For example, when designing a remote control or computer mouse, 3D printing makes it easy to create several test pieces to see how well they fit in the hand and whether customers like them. Unlike traditional manufacturing, where preparing the moulds for each part is expensive and time-consuming, 3D printing makes it possible to create a prototype in a few pounds and virtually instantly.

3D printing of prototypes isn't just about looks or ergonomics - it can also print functional models. For example, with a game controller, you can print its "body," insert the electronics, and actually test it. This allows companies to quickly and efficiently test a variety of products in their functional form.

While 3D printing is not suitable for mass production, it is invaluable for prototyping!

Architecture

3D printing today offers architects great opportunities to bring their designs to life. Whereas previously building models were laborious and time-consuming to create, today 3D printing makes them fast, cheap and accurate. This allows architects to present real building models to clients, which helps them understand the design better than from drawings or computer visualizations.



3D print of house <https://ww3.rics.org/uk/en/modus/built-environment/construction/cobod-machines-3d-printing-homes.html>

And it's not just models - 3D printing is starting to be used in the construction of real

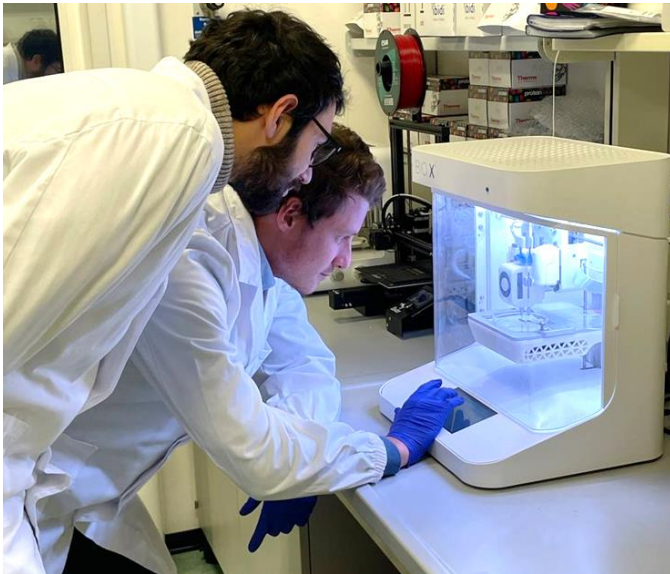
houses. Concrete printing makes it possible to build an entire smaller house in a matter of days with minimal cost and material waste. For example, Apis Cor printed the complete exterior walls of a house in 24 hours and at a fraction of the cost of traditional construction. Thus, 3D printing gives architects new ways to create practical, affordable and customizable homes.

Medicine

In medicine, 3D printing has huge potential and could revolutionise patient care. Today, it is already being used, for example, in the production of implants that can be tailored to each patient, improving accuracy, reducing costs and shortening production times. Printing from biocompatible materials such as titanium can create safe and durable replacements for joints or bone parts.

One fascinating industry is bioprinting, where special "bioinks" with living cells are used instead of plastic. In this way, cellular structures such as cartilage or even parts of organs can be printed. These technologies have the potential to test medicines and treatments without the need for animal

experiments and offer the chance to print the organs of the future.



Bioprint <https://www.cellink.com/customer-spotlight/innovative-silk-bioink-for-3d-bioprinted-bone-marrow-tissue-models/>

In dentistry, 3D printing makes it easier to create models of teeth, crowns and braces that fit perfectly. Thanks to 3D printing, a dentist can prepare a crown in less than an hour on-site, which is faster and cheaper than traditional methods. Plus, thanks to the 3D scan of the patient's teeth, it's also very accurate!

In addition, 3D printing is also proving useful in medical education because it allows the creation of realistic models of human organs or tissues that are inexpensive and easy to preserve. The technology thus improves both patient care and the training of future doctors.

DIY and better repairs

In homes and schools, 3D printing provides a practical solution for everyday repairs and small projects. It used to be common to fix broken things, but today we often throw things away and buy new ones. This is not only expensive, but also not environmentally friendly - we simply produce a lot of waste. However, thanks to 3D printing, we can easily create spare parts at home that manufacturers often don't sell or are too expensive.

There are shared model databases on the internet where people offer their designs for spare parts or other practical tools for free. In some community workshops, people can then use 3D printers if they don't have them at home. Whether it's a phone holder, a grille for the air conditioning in your car or a repair part for your camera, 3D printing can create exactly what you need while promoting a sustainable approach to the things around us.

Art

3D printing opens up new possibilities for artists to express and experiment. It allows artists to create unique sculptures, interior elements or even fashion accessories that would be difficult to produce using other techniques. In addition to creating new artworks, 3D printing also allows old artworks to be replicated, which helps in

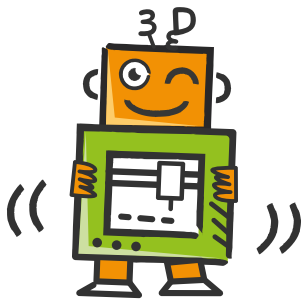
protecting them or creating miniatures without having to put the original at risk.

3D printing is also used to make art accessible to the visually impaired. For example, Finnish artist Marc Dillon's Unseen Art project brings famous works of art, such as the Mona Lisa, into a tangible form so that visually impaired people can 'see' them with their hands. This approach allows them to experience works that would otherwise remain out of their reach.



Obrázek 1 <https://www.fastcompany.com/3049707/this-hermit-crab-has-a-glass-cathedral-for-a-shell>

Some projects are truly unusual, such as "Why Not Hand Over a 'Shelter' to Hermit Crabs" by Japanese artist Aki Inomata. She designs 3D printed shells for hermit crabs that are not only comfortable but also shaped like famous architectural landmarks, such as downtown Paris or windmills. 3D printing thus allows for a creative fusion of art, design and nature.



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Using 3D printing in everyday life - renovation, DIY and upcycling

3D printing finds its place everywhere nowadays, one could say that if we can imagine it, it can be made. 3D printing saves not only time, but also your wallet and can make a tailored object for us in a relatively short time. Where can we find and use it?

Renovation

Has something broken at home and you are looking for a spare part? Thanks to 3D printing, you can easily design the broken item or download the finished model, modify it as needed and print it. It could be a piece of furniture, a cabinet handle, a broken bearing in a blender, a missing Lego piece, a broken keyring, a missing hook in a cupboard, or even a brand new spice jar or a replacement for a cracked hinge on a food box lid. Thanks to 3D printing, you can also

add your own touch to the model and take the item to a whole new level.



[You can print almost anything today - a new lamp cover or a whole house](#)

FUN FACT: *Did you know you can easily print out IKEA accessory parts?* The retail chain offers some of its product collections as free 3D models in its planner database to work with when furnishing and modelling your own living space. You can also make some of the products yourself thanks to the handy 3D DIYers - for example, the various

modifications of the handles for the [SKÅDIS multifunctional hanging walls](#).

Upcycling

What can be made when, apart from recycling, when you can use 3D printing to give old things a completely different dimension? By combining these techniques, you can not only bring all sorts of pieces of waste back into life/circulation, but also take them to the next level - creating interior accessories (e.g. lamp covers, [vases](#), various notebook holders), outdoor gadgets (bird feeders, gardening supplies for planting) and lots of other ideas. Whatever it is, it is always possible to take a piece of an old item (for example, an empty shampoo container) and add a 3D printing element to it (e.g. a cap with holes for inserting pencils) to create something new and original (for example, a stylish recycled school supply holder). At the same time, it is possible, for example, to make a completely new printing material from old PET bottles, which can be melted down again in the event of a failed piece of

[3D print and transform it into something new or another filament.](#)



[Treasure from the trash: A plain old food jar can be transformed into a stylish accessory with a little bit of skill thanks to the designed 3D printing packaging.](#)

FUN FACT: Did you know that there are various contests on [Printables.com](#) that also feature the use of 3D printing in combination with upcycling?

DYI/ Handicraft

3D printing has recently become a very popular technology, especially among [modellers](#) - it can be used to print parts of buildings and entire streets, mountains, planes, cars, individual small objects from a garbage can to realistic-looking figures, statues, to post-apocalyptic scenery and much more*. 3D printing is also used in the production of fashion accessories such as jewellery or [handbags](#), artwork or in the candy industry to make hooves for silicone cake moulds. These objects then undergo post-processing, where they are further sanded, painted with model paints, varnished, etched with solvents, etc. More information about this technique can be found in a separate chapter.



[Medieval village diorama made with 3D printing](#)

* To obtain high quality and smooth detailed [models](#) without visible layer transitions, 3D

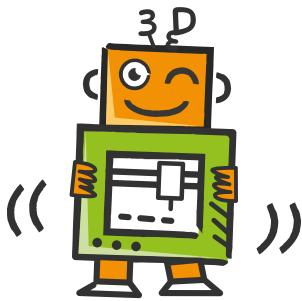
printing using [SLA](#) technology is increasingly used today, where high-precision details can be achieved by curing the resin.

FUN FACT: *Did you know that even within the popular geocaching community, a variety of art objects directly created using 3D printing can be found in various cities around the world?* These cunningly hidden treasures are left in interesting places by artists such as [3Dfiti](#) - you can see a map of the locations [here](#).

QUESTION: Where can you encounter 3D printing in your everyday life?

CHALLENGE: Try to think of 3 ways to use 3D printing in your home in a smart way - what all can you think of? **

** You can use it to make pencil holders, retrofit broken parts, cupboard holders for pot lids, etc. 😊



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Ways to use 3D printing in school

The implementation of 3D printing in primary school education enables the creation and use of new teaching aids. Pupils can not only work with educational models in the classroom, but thanks to methodological support they can also actively participate in their creation. Thus, we distinguish two basic directions of 3D printing use:

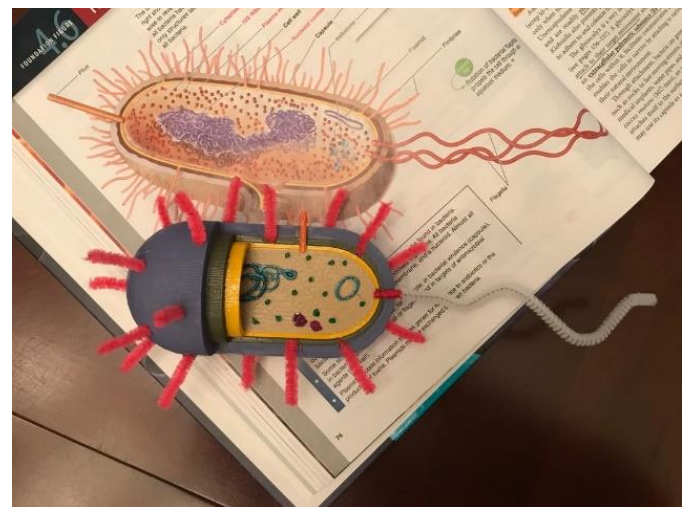
- Printing of models by teachers and their use in teaching to illustrate objects, phenomena or processes
- Modelling and 3D printing of objects by students themselves in STEM fields

3D models as visual aids

3D printing allows the creation of physical models that help students better understand abstract concepts, as well as more complex concepts. The main advantages include both visualisation and the ability to be physically manipulated by

pupils. This can be used in many subjects at school:

Natural History and Primary Science - models of body parts and organs, internal structures and cells including their disassembly, animal skeletons or plant structures and natural structures.



<https://www.thingiverse.com/thing:2695890>

<https://www.thingiverse.com/thing:3021328>

History and geography - historical objects and their replicas, buildings and architectural monuments and various

landscape

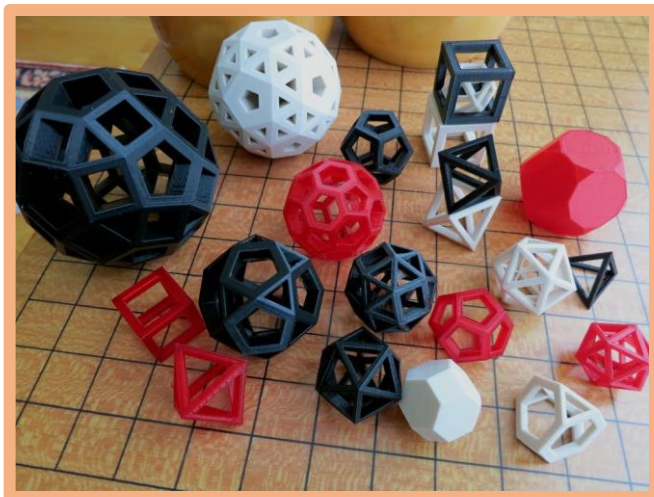
features.



<https://www.thingiverse.com/thing:2709566>

<https://www.thingiverse.com/thing:1355370>

Mathematics and physics - geometric shapes and their parts, more complex patterns, simple machines and mechanisms or models of planets and the universe.



<https://www.thingiverse.com/thing:233540>

<https://www.thingiverse.com/thing:1622735>

Art and work activities - creative creation of own objects, figurines, puzzles, puzzles,

games, etc., their printing and further processing such as painting.

Technical and STEM skills in cross-curricular projects

In engineering and computer science subjects, students can design and model in 3D applications from simple objects such as a keyring to more complex constructions, thus improving their imagination and technical skills. Many projects can involve multiple subjects. Designing a functional bridge will involve maths, physics, computer science and art. Technical design can include school-appropriate items - a pencil stand, a desk organizer, etc. Students can work in groups, prototype and improve their designs by testing them in practice after printing them on a 3D printer.



<https://www.thingiverse.com/thing:1720192>

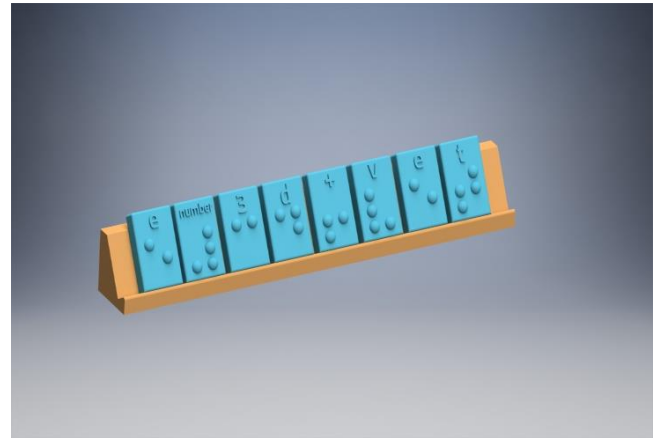
- Designing and printing custom prototypes of various tools and instruments
- Experimenting and solving practical problems, repairs and improvements

- Developing teamwork, critical and logical thinking skills

Personalised teaching and inclusion

Due to the ease with which teaching aids can be adapted to the specific needs of pupils, 3D printing is a great asset for personalised learning and support for pupils with special educational needs.

- Visual impairment - tactile maps, graphs, markers for orientation in space, relief models of objects to get a concrete idea of the shape or surface
- Auditory impairment - models of communicative gestures, alphabet signs, visualisation of abstract concepts in different subjects
- Learning disabilities - a range of aids can be used for different specific learning disabilities, such as tactile models of letters and words for dyslexia, interactive objects for concentration problems, etc.
- Tailor-made aids - individualised aids adapted to the learning style of specific pupils, practical anatomical models, aids for interaction and group work

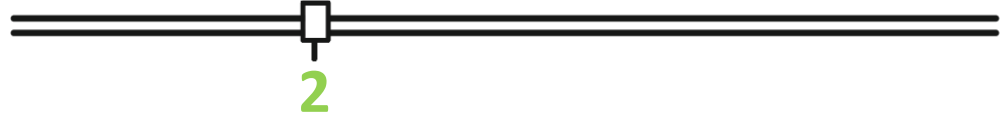


<https://www.thingiverse.com/thing:3824937>

Ecology & Sustainability

3D printing hands-on projects can show pupils the impact of environmental and sustainability decisions on the planet.

- Production of environmentally oriented items for school - replacement of disposable products, lunch box, pencil holder, litter pickers, classroom waste sorting aids
- Recycling plastics - discussing the possibilities of reusing plastics, filament production, circular economy
- Efficient design - designing 3D objects with consideration of the amount of materials, lightweight hollow structures
- Repairing damaged items - spare parts, repairing school supplies instead of throwing them away, thus learning the principle of sustainability



Types of 3D printers in a nutshell

There is a wide range of 3D printers on the market, not only by manufacturer or price, but also by the type of technology used. Each type of technology has its advantages and disadvantages, so we will briefly introduce them here.

1. FDM/FFF (Fused Deposition Modeling / Fused Filament Fabrication)

FDM printers work with plastic filament that is on a spool. This filament is heated in the print head (extruder) and the molten plastic is applied to the print bed layer by layer. After one layer is applied, the print head or bed is moved to apply the next layer. This process continues until the entire model is complete. These are the most widely used

3D printers and are also the most commonly found in schools.



Figure 1 Prusa MK4S printer -
<https://www.prusa3d.com/cs/produkt/3d-tiskarna-original-prusa-mk4s-5/>

Advantages:

- **Low cost:** FDM printers are affordable and easy to maintain. Materials such as PLA, ABS or PETG are also cheap and readily available.
- **Ease of availability:** a very popular technology with many manufacturers and community support.

- **Variety of materials:** You can print with materials of different properties - flexible, temperature resistant or biodegradable.

Disadvantages:

- **Lower precision:** details and surface quality are not as fine as SLA or SLS.
- **Visible Layers:** the resulting models often show visible layers, which may require further processing (sanding, painting).
- **Slower Printing:** For more complex models, printing can be time consuming.

Usage:

- **Prototyping:** ideal for quickly creating basic models or test prototypes.
- **Hobby Projects:** home use, scale model making, toys or decorations.
- **Functional parts:** Replacement parts or practical household items.

SLA (Stereolithography)

SLA printers use a liquid resin that is cured using a UV laser. The laser selectively illuminates the areas on the surface of the resin to be cured, creating a single layer. After each layer, the platform on which the model is printed is moved and the process is repeated.



Figure 2 SLA Prusa SL1S printer with UV curing station.
https://blog.prusa3d.com/cs/predstavujeme-original-prusa-sl1s-speed-nejrychlejsi-stolni-sla-3d-tiskarnu_51436/

Advantages:

- **High precision:** the SLA printers can produce very precise details, which is ideal for models that require precision workmanship.
- **Smooth surface:** The resulting models have a significantly smoother surface than models from FDM printers.
- **Small models capability:** thanks to the precision and finesse of the laser, even very small objects can be printed.

Disadvantages:

- **More costly to operate:** resins are more expensive than filaments and more difficult to handle.
- **Health risks:** resin can be toxic before curing!
- **After-print curing:** after the model is printed, it must be rinsed in isopropyl alcohol and cured with UV light.

Usage:

- **Jewellery:** precise prototypes and designs.
- **Healthcare:** production of dental moulds, orthodontic appliances.
- **Design models:** Decorative objects and miniatures.

DLP (Digital Light Processing)

DLP printers work similarly to SLA, but use a digital projector instead of a laser. This projector illuminates the entire layer at once, making the process faster. The resin is cured where the light hits.

Advantages:

- **Speed:** Since the projector illuminates the entire layer simultaneously, printing is much faster than SLA.
- **Accuracy:** The results are very similar to SLA printers, with a high level of detail and a smooth surface.
- **Easier maintenance:** projectors have fewer moving parts than lasers, which simplifies maintenance.

Disadvantages:

- **Similar to SLA printers**

Usage:

- **Design and visual models:** sculptures, product prototypes.

- **Healthcare:** moulds for dental implants or surgical instruments.

SLS (Selective Laser Sintering)

SLS printers use a laser to melt powdered material (e.g. nylon). The laser selectively fuses the powder into the desired shapes, layer by layer. Unnecessary powder parts remain loose and serve as support for the print.



Figure 1 SLS tiskárna SINTRATEC S2.

<https://www.na3d.cz/p/3351/tiskarna-sintratec-s2?pp=375c7134>

Advantages:

- **No supports:** you do not need to print support structures because the unused powder serves as a support.
- **Functional parts:** The resulting objects are strong, durable and can take complex shapes.
- **Speed:** Greater efficiency when printing multiple parts at once.

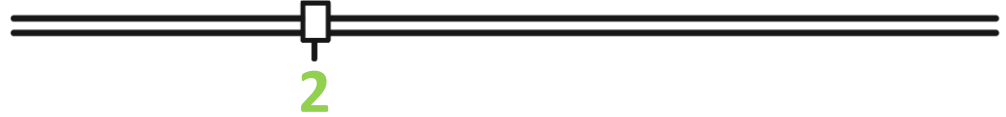
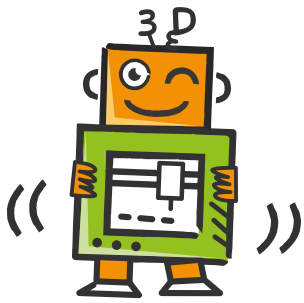
Disadvantages:

- **High cost:** printers and powder material are more expensive.
- **Coarser finish:** The resulting models may have a slightly grainy finish.
- **Maintenance:** powder requires recycling and careful handling.

Usage:

- **Industrial production:** functional prototypes, small series of products.
- **Final products:** housings, tools, components.

In addition to the ones mentioned here, there are a number of other 3D printing technologies (PolyJet, DMSL, LDM), these are mostly either variations on the ones mentioned here or are very specific industrial or medical applications. [More can be found here.](#)



FFF printers suitable for use in primary schools

3D printing is becoming an increasingly popular tool in education, thanks to its ability to transform abstract concepts into real-world form. Thanks to 3D printing, students' creativity and technical skills can be developed, while at the same time motivating them to actively participate in the learning process and leading them to collaborate with each other. One of the most affordable and widely used types of 3D printers ideal for primary schools is the aforementioned FFF technology. There is a plethora of 3D printers on the market today that can be purchased at a fraction of the price and [enrich the learning experience](#) with modern technology.

FFF 3D Printer Selection Parameters

As already mentioned, FFF 3D printers are a great tool for modern teaching that can enrich the educational process and prepare students for a future full of technology.

When choosing an FFF 3D printer for school, we should keep in mind several parameters that we will need during the lessons, clubs or after-school program.

Worth mentioning:

- **Printer purchase price and availability** - price versus output print quality and costs associated with print material; printer maintenance and troubleshooting.
- **User-friendliness** - how easy and intuitive it will be for teachers and pupils to operate the printer, including the relevant software.
- **Safe and versatile use** - integrated safety features in the event of a printing problem (filament detection, overheat protection, emergency switch to shut down in case of an error during printing, etc.) and the ability to print from a variety of material types from PLA to PETG,

FLEX and more in the creation of various projects and tools across subjects.

Application of a 3D printer at primary school



3D printing in school finds its application across subjects.

In addition to Informatics, the 3D printer can be used for lots of ideas in other subjects. In mathematics, models can be created to understand geometry; in science, chemistry, physics or history, it can be used to make models of molecules, cells, historical buildings or even contours or geographical maps; in art and work activities, various mechanical prototypes of products can be designed or individual models can be further modified, painted, glued, sanded and transformed together with other materials into various utility products (such as bird feeders, pencil holders, additional parts for robotic toys or the production of their own technical construction kits) or works of art

(various sculptures, classroom decorations, depictions, model schools, etc.) It is also useful for creating special aids for pupils with various special needs. In all these areas, the 3D printer and the creation process helps with deepening knowledge as well as developing technical literacy and creativity.

Printers for primary school needs



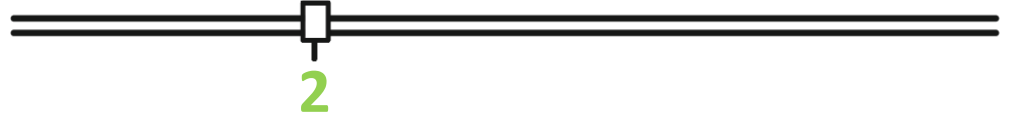
[3D printer Prusa MINI+](#)

When it comes to choosing a 3D printer for school purposes, it is advisable to look at price, safety and good handling. These printers include, for example, models from [Prusa Research's](#) Prusa series, which also offers [free 3D printers to schools](#). In addition to a sophisticated methodology for printer set-up, operation and solving printing difficulties, the company offers training, [competitions for students](#) and many other things, including its own model [database](#).

Another widely used 3D printer is the [Ender](#) brand from Creality, which, in addition to its affordability, offers relatively high quality and accurate printing. As with Prusa, the printer has a broad base of support from users and is suitable for beginners.

If you have any doubts about whether a particular type of printer will suit you, you can also [rent a 3D printer](#) for school before you buy it. Of course, these options may vary

depending on the country or region in which your school is located.



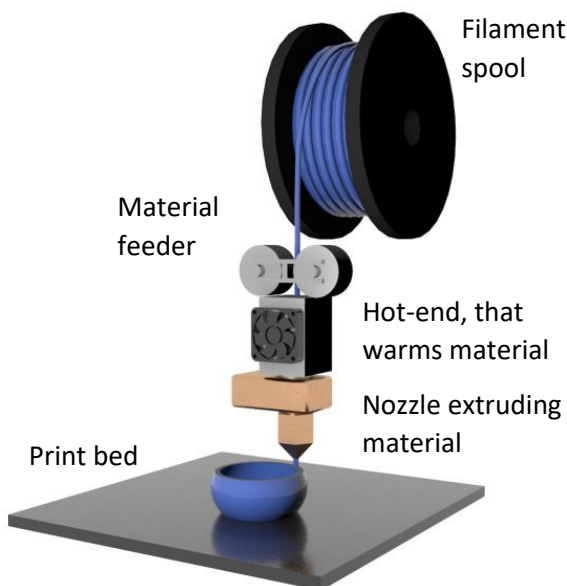
Elements of FFF printers

FFF (Fused Filament Fabrication) printers are the most suitable and widespread for use in primary schools. Although the different printers available on the market differ in size, the way the axes move and other parameters, in principle they are all the same and consist of the following basic components:

Print material and its feeding

Filament spool - Filament is a material (typically plastic) in the form of a print string of a precise diameter (usually 1.75mm) wrapped on a spool and placed in a spool holder on or near the printer. We will learn more about Materials later in the text.

Filament feeder - has the task of gradually and accurately moving the filament string further into the printhead hotend. The feeder can be designed as a part of the print head directly on the sliding arm or separately in the printer frame and then pushing the material further from the print head by using the bowden. TIP: For proper feeding of the material, the pressure of the feed wheels is crucial so that the material does not slip and grind and at the same time the material does not squeeze or jam.

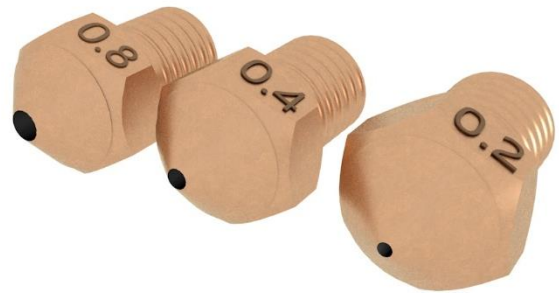


Print head

The basic part of the printer is the **print head**. Its design varies slightly from printer to printer, and the quality of the entire construction is largely responsible for the quality of the print. It mainly affects the operating temperature range and its stability and the quality of cooling. In addition to the filament feeder (see above), it may contain the following main components:

Heating block with cooling - the heating block, typically a metal block that heats the material, must maintain a stable temperature for proper filament fusing, which is why it also includes passive and active cooling of the print head. This whole part of the printer is also called the **hot-end**.

Print nozzle - typically a metal nozzle with a precise diameter of the hole through which the material is extruded. The basic dimension is 0.4mm but by replacing the nozzle with a smaller or larger one, it is possible to achieve finer resolution in the x/y axis and therefore greater detail or, conversely, faster printing for larger (and less detailed) prints. Nozzles can also be found in various materials e.g. with a corundum core for stronger and more abrasion resistant filament flow.



Cooling of the printed material - fan(s) with targeted air flow on the printed material accelerate its cooling, the quality and accuracy of cooling mainly affects the printing of overhangs and bridges.

Print bed

The print bed is an important part of the printer and its main job is to keep the material firmly attached to the bed throughout the printing process. It must be calibrated with the print head so that the distance of the nozzle from the bed is constant and accurate at all points and, especially on the first layer, the material is pressed against the bed. In terms of materials, different surfaces are commonly used. The most common are PEI (a type of thermoplastic deposited on a thin metal substrate) or glass. However, many manufacturers offer special pads, and different surfaces are also differently suited for specific printing materials.

Bed heating - most printers offer a heated bed. Heating the bed causes the material to adhere better during the printing process. In the event of an unheated print plate or adhesion problems, it is advisable to apply adhesive (office glue stick) before printing.

Printer construction

In terms of the printer design, the frame, the cover and especially the movement of the individual x/y/z axes are essential. The strength of the printer frame will affect the accuracy of the axis movement. Prusa printers have a "U" frame for the x/z movement of the print head (sideways and up/down) and a y-axis shifting bed (forward/backward). On the Prusa Mini printer, the frame is further simplified to just a single-sided arm. Some other printers (e.g. Ultimaker) move the arm in the x/y axis while the bed moves in the z/down axis. One can also encounter so-called "delta" printers with a non-moving fixed bed and a print head suspended on three arms and vertical axes for complex 3D movement.

Another element of the printer is (or is not) its enclosure. A large number of printers are not covered as standard, but there are two major advantages to using a covered printer:

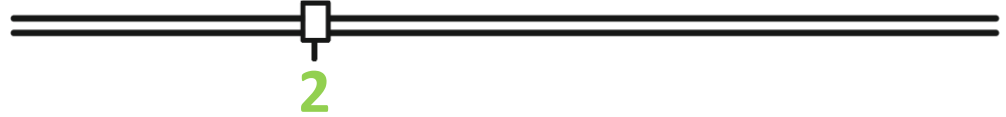
- **Control** over printing conditions in terms of more stable temperature, preventing airflow, etc.
- **Security** - in terms of placing the printer in schools, preventing access to the hot-end is safer.

Display and connectivity

The last of the basic components of the printer are its input and output elements. Most printers have some type of display with menus for print input and printer settings. Another element is the interface for inputting print data. Printers can have different interfaces - connectivity, most commonly a memory card (SD) input, USB flash drive, LAN port or WiFi.

Spare parts

Many components are subject to wear and tear during printing and need to be replaced over time. These include nozzles, bowden, washers, etc. Moving parts, axles, gears, etc. must be lubricated with a suitable lubricant as part of maintenance. In general, a large part of the printer components are disassemblable and replaceable, including the entire print head.



Basic handling of the FFF 3D printer

The classic FFF printers today are not particularly complicated and will largely guide you with the hints on their display. However, it's a good idea to know the whole printing process so that you don't miss a crucial part and have an unpleasant time with a poorly printed model or even a damaged printer.

So let's go through the basic steps of how to work with the printer so that we can print!

Inserting the filament (1):

- On the printer, select "Filament Insertion" and choose the type of filament to be inserted from the menu. According to this, the nozzle and the pad will heat up to the right temperature.
- Cut/ trim the filament into a tip before inserting it into the extruder.

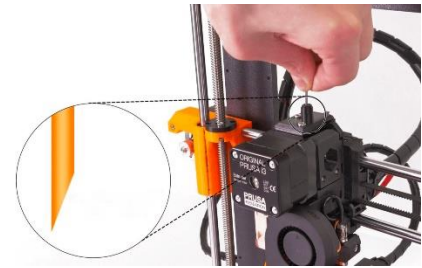


Figure 1 Insertion of the filament into the extruder and demonstration of the correct cutting of the filament tip. Modified from: <https://muni.cz/go/99d17d>

- As soon as the printer tells us it is thermally ready, we put the filament into the extruder.
- Finally, we check that the new filament is extruding and that it has the desired color. If necessary, we let the printer extrude more.
- If there is already some filament in the printer, select "filament change". Wait for the printer to warm up and eject the filament from the extruder. Remove the filament and insert the new filament.

- - Check if there is any knot on the filament spool or if the filament is otherwise tangled on the spool! Avoid unnecessary problems with broken filament or clogged extruder!

Bed Alignment (2):

- The bed must be level and the nozzle must be the correct distance from the bed.
- Most printers nowadays do the alignment automatically, mostly at the start of the print or even when starting the printer. In some cases, if the ABL doesn't do its job properly (or with older printers), manual bed leveling is required. Manual bed leveling requires a sheet of paper to be inserted between the nozzle and the bed at various points on the bed. A good distance is one where the paper is free to pull out but scrubbing.



Figure 2. Aligning with a sheet of paper. <https://muni.cz/go/cc78df>

Preparing the print bed (3):

- The bed mat must be cleaned regularly! Often just washing the mat is enough, but for a good cleaning, isopropyl alcohol is ideal.
- For prints where there is a risk of peeling (or if this has already happened to the model) we can apply a thin layer of glue or hairspray to the bed.

Loading G-code (4):

- Using an SD card, USB disk or online application, load the print file prepared in the slicer into the printer.
- Select the desired file in the printer menu and start printing. The printer heats up the nozzle and bed according to the settings and starts printing.

Checking the first layers (5):

- It is important to check the first layers at the beginning of the print process. If they are printing correctly, if the print has not come off the bed, and so on.
- If there is a problem in the first layer, stop printing, throw away the already printed filament and try to solve the problem (see troubleshooting chapter for more information).

Print monitoring (6):

- We do not interfere with the printing process (although more experienced users can change the print speed or the bed temperature).
- We check the print continuously to detect any errors and prevent damage to the printer - for example, a torn print, a clogged nozzle, deformation of the printed model, etc.
- If a problem arises during printing, do not try to save the print in progress at any cost! The model can be printed again, but a damaged printer is a bigger problem!

Removing the model from the bed (7):

- After printing, let the model cool down a bit and remove it from the bed tray.
- If the print can't be removed from the mat easily, you can use a spatula for example - be careful not to damage

the model, but especially the print bed!

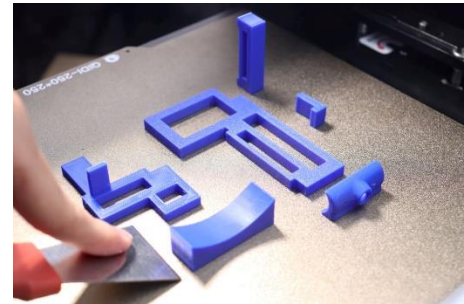


Figure 3. Removing the print from the plate with a spatula.
<https://muni.cz/go/c076bb>

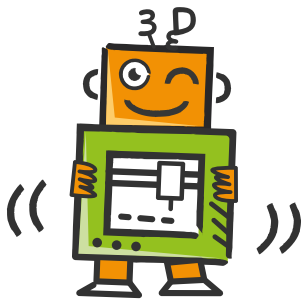
- For flexible mats (e.g. Průša printers), remove the entire mat with the model and gently bend it - the print should peel off on its own.

Turn off the printer (8):

- Turn off the printer if you are not going to print again immediately.

Printer maintenance (9):

- It's not necessary to do this after every print, but once in a while it's a good idea to clean the nozzle, clean the bed properly and check the wear on the parts - if the drive belts are well tensioned, bearings lubricated and so on.



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Troubleshooting - the most common printing problems and their solutions

Various complications can occur during the printing process, such as adhesion errors, model deformation, printing jams, etc. These problems can be caused by parameter settings, material quality or poor preparation. Let's take a look at the most common problems, possible causes and solutions.

The print does not adhere to the bed

One of the most common problems is insufficient adhesion, i.e. the model does not stick well to the bed, it **peels off**, or parts of it come off and warp, or the whole model starts to shift, which often results in a **tangle of threads**. When the print comes off the bed, it can also start to stick to the nozzle and hot-end itself.

Solution: First, check if the bed is not greasy before printing. Next, check the alignment of the bed and the calibration of the first layer. When extruding, the first layer must be pressed against the bed by the nozzle (but it must not be pressed so hard that there is no room for the actual filament extrusion and the nozzle practically rides and scratches on the bed). Increase the temperature of the pad. Alternatively, apply office glue to the bed. An enclosed print chamber that stabilizes the temperature and prevents airflow can also help with lifting the edges of the print.



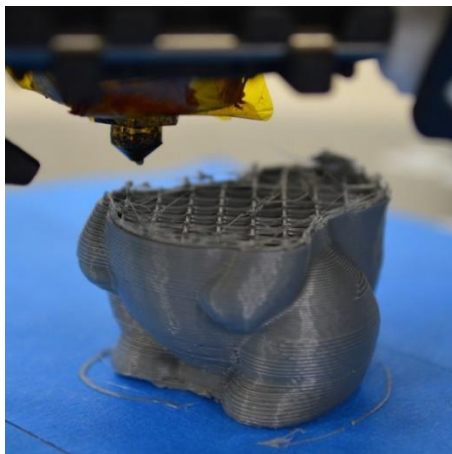
https://help.prusa3d.com/article/first-layer-calibration-i3_112364

Filament is not extruded

Apart from simply running out of filament, there are two common causes, a **clogged nozzle** or a problem with **feeding the material into the hot-end**.

Solution: If the problem is a clogged nozzle or other part of the hot-end, it is possible to attempt to clean it either by cold-pull or by disassembling parts of the hot-end. See [here for more information on cold-pull](#).

Another possibility is a problem with the feed. Poor pressure on the feed wheels can cause filament grinding or slips and the pressure needs to be adjusted correctly. If the filament has been grinding for a long time, the feeder will need to be cleaned of filament residue. It is also necessary to watch for filament running out, breaking or string tangling.



<https://www.obico.io/blog/step-by-step-guide-unclogging-your-3d-printer-nozzle/>

Parts of the model are twisted, melted or crumbling

The printed model may **melt** or **curl**, details are not clearly visible and **overhangs** or **bridges** are difficult to form. This can also cause filament **tangling** on parts of the model.

Solution: Having the correct filament melt temperature and cooling settings is essential for quality printing. It may be necessary to lower the temperature. When creating overhangs and bridges, good cooling is also needed, but the speed of the print also plays a role. If the model contains larger overhangs or bridges, you may need to turn on print **support creation** in the slicer.

Broken filament

Filament **snaps** mid-print, halting extrusion and leaving gaps or failed layers. Causes include old or brittle material, excessive spool tension (for example if twisted in the spool), sharp feeder path, or too-high retraction.

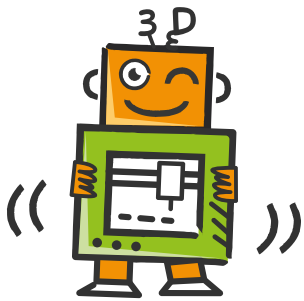
Solution: Dry or replace aged filament, reduce tension by repositioning spool and checking rollers, smooth filament path, lower retraction distance/speed, and pause to reload filament before resuming the print.

Mechanical and electronic printer problems

A 3D printer contains many mechanical and electronic parts that can fail or wear out. To prevent problems, the printer needs to be maintained - specifically cleaning (nozzle, extruder, feeder), lubricating moving parts

such as axes. Attention should also be paid to bearings and fans. Last but not least, it is advisable to update the printer firmware. Further steps can be found, for example, [here](#).

Many other problems and their solutions [can be found here](#).



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Types of 3D printing materials using FFF technology

In order to print different objects, we need different materials that meet certain properties. Sometimes temperature plays a role, sometimes safety of use, sometimes we want the final product to be flexible, sometimes we want it to withstand harsher conditions and longer-term handling. So there are different 3D printing materials for different requirements that we can work with in school. Let's briefly introduce them.



Filaments can be found in various colours and compounds
(source: for3dtisk.cz)

PLA

The most widespread and used material, which is easy to print and subsequently easy

to process. PLA is a biodegradable and non-toxic polymer, making it safe to use in school environments. While its low printing temperature and ease of printability results in a lower strength final product, it also simplifies the 3D printing process itself, making it an ideal material for beginners and younger students who are just becoming familiar with 3D printing. Finished prints made from this material can be further finished (e.g. painted, varnished, sanded, glued, etc.), which can add an extra dimension to the products and make 3D printing useful in other subjects such as Design and Technology or art education.

Advantages: easy to print, easy to process (painting, varnishing, sanding), non-toxic material - safe for school environments

Disadvantages: lower print strength and low stability at temperatures above 50°C and mechanical stress.

ABS

ABS is a widely used material for 3D printing due to its high strength and impact resistance. It is also temperature resistant, making it a suitable material for objects that will be subjected to higher temperatures or mechanical stresses. However, printing from ABS releases fumes that can be toxic and good ventilation is essential. ABS is suitable for the production of functional prototypes, tools and toys.

Advantages: resistant to impact and higher temperatures, possibility of smoothing with acetone.

Disadvantages: - Vapours are released during printing (ventilation required), tendency to warp during printing (heated bed required, ideally enclosed printer).

ASA

It is a material very similar to ABS with the addition of compounds that improve its properties compared to ABS.

ASA is highly resistant to UV radiation and weather effects, which ensures its long life even in harsh conditions. It is therefore suitable for printing items that will be exposed to sunlight and various weather conditions, such as garden decorations, birdhouses, outdoor furniture or automotive parts.

In the case of use in school environments, it is therefore necessary to take into account the lower processability compared to PLA and to take into account the safety of the pupils - for example, having a laboratory with sufficient ventilation and an enclosed 3D printer in which printing from this material can take place without endangering health.

Advantages: high resistance to weathering (UV radiation), good mechanical resistance.

Disadvantages: vapours are released during printing (ventilation required), tendency to deform during printing (heated bed required, ideally enclosed printer).

PET a PETG

PET and PETG are two different types of polyethylene terephthalate. PET is known for its strength, hardness and good chemical resistance. It is often used for bottles, packaging and textiles. PETG is a variant of PET that contains glycol, which improves its 3D printing properties. PETG is more flexible and durable than PET, but still retains high strength and chemical resistance. PETG is less brittle than PLA and can be used to produce functional parts and prototypes that require greater mechanical resistance.

Advantages: stronger than PLA, PET - strength and hardness, good chemical

resistance; PETG - flexibility and less brittleness.

Disadvantages: Moisture sensitivity, more difficult to process during printing (PET), need for good ventilation during printing (PETG).

NYLON

Nylon is a synthetic polymer that is known for its high strength, wear resistance and chemical resistance. Nylon is also known for its smoothness and low friction, making it an ideal material for printing functional parts such as gears, bearings and other mechanical components that require high durability and precision.

Nylon has excellent mechanical properties, but its printing can be more challenging due to its tendency to absorb moisture from the surrounding environment. This can lead to printing problems if the material is not stored and dried properly before use.

In a school setting, nylon filament can be useful for creating a variety of hands-on and educational models. Due to its strength and durability, nylon is ideal for making mechanical parts to demonstrate physical principles. Students can print models of machines, or create durable tools and gadgets that can withstand frequent use and experimentation.

Advantages: high strength and durability.

Disadvantages: more demanding printing and need for a dry environment.

TPU – FLEX

TPU - Flexfilament is known for its high flexibility and durability. This material is ideal for printing flexible and pliable objects such as various seals, protective covers, elastic joints, moulds, or even shoe soles. In a school environment, TPU filament can be used for a variety of practical and creative purposes. It can be used to print models for physics to demonstrate material properties such as elasticity and strength, various smaller pads and rubber caps for containers, stoppers, rubber bands or models with flexible parts. This filament is also suitable for making protective packaging and tools that can be used in school projects and experiments.

Advantages: high flexibility and impact resistance, abrasion and chemical resistant

Disadvantages : More difficult to print (lower speed and direct-drive extruder recommended), longer printing time due to lower speed.

Special filaments

There are many special types of filaments that expand the possibilities of 3D printing. We will list just a few here, but the range of filaments is growing all the time. New and specialty filaments tend to be more expensive, and some require more user experience, but they may be ideal for your print:

Wood filament: contains tiny wood particles combined with PLA, allowing you to print objects with an imitation wood look and texture.

Metal Filament: contains metal powders mixed with a plastic base, allowing objects to be printed with a metallic appearance and higher weight than conventional plastics.

Phosphorescent filament: this type of filament glows in the dark when exposed to light. It is ideal for decorations, safety signs and creative projects.

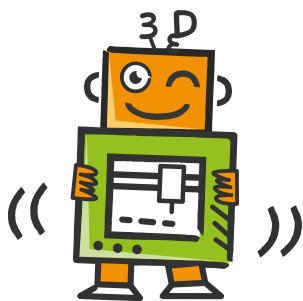
Carbon Filament: contains carbon fibers mixed with a plastic base, providing high strength and rigidity. This filament is ideal for printing mechanical parts and structures requiring greater durability.

Water-soluble filament: Often made from PVA (Polyvinyl Alcohol), this filament is used as a support material when printing complex objects. Once printed, the support material

is easily soluble in water, making it easier to remove supports.

Fabric filament: The filament contains textile fibres mixed with a plastic base, which allows printing objects with a fine fabric-like texture.

Antibacterial filament: Contains additives to prevent bacterial growth, making it ideal for printing medical and hygiene products.



Acquisition and creation of models for 3D printing

3D printing and working with three-dimensional models may seem complicated at first, but there are actually many simple and accessible ways to incorporate 3D objects into the education process.

In the following chapters, we will explore several ways to acquire 3D models:

Database search

There are a number of specialized websites that offer thousands of freely available 3D models for immediate download. This makes it easy to find models for science, maths, geometry or art and use them directly in teaching praxis.

Creating models using a 3D scanner

For some projects, it is worthwhile to take a scan of a real object (e.g. tree leaves, historical objects or school tools), which students can then explore digitally. Today, scanning is not just the domain of specialist labs - even in everyday practice, you can find affordable 3D scanners or use mobile apps.

Modelling in 3D software

The creation of 3D models itself provides pupils with another dimension - they develop imagination, spatial understanding and creativity. There are many simple programs on the market for beginners to create their own models as part of a project or teamwork - we'll focus mainly on working in TinkerCad, but we'll also show that it's not the only one.



Databases of 3D models

There are a number of large databases offering 3D models available on the Internet. Many of them provide models for free, while others require a fee for access or for downloading specific models.

However, not all databases are aimed directly at 3D printing, which means that some models may not be suitably optimised for printing processes. On the contrary, some platforms offer **methodological and didactic materials** in addition to the models themselves, which facilitate their use in school education. If the database is focused on 3D printing, it often includes instructions or other information.

The following overview contains a selection of online resources with a short description of their content. Most of these databases are not highly specialised and include thousands of models of various kinds - from

figures, spare parts and design objects to useful household gadgets and more.

Thingiverse – www.thingiverse.com

Probably the most well-known and very extensive database of free 3D printing models available. The database is not specialized, so we can find objects from many categories. It is a community database, so we can find not only instructions for 3D printing, but also a discussion of the models or a gallery of prints of the model. Thingiverse also includes a **section for education**

<https://www.thingiverse.com/education>.

Printables - www.printables.com

The database directly from the makers of Prusa printers is Printables. Here we also find, among other things, a Learning section divided by learning areas and of course a lot of models divided into categories.

MakerWorld – www.makerworld.com

The third large database is MakerWorld, it focuses primarily on BambuLab printers and therefore often contains prepared g-code for these printers, but when you download the model you can of course use it and slicing it for any 3D printer.

BE3DAcademy - be3dacademy.ysoft.com

The YSoft database offers models divided into lessons by age and educational area. Some sections and models are available for free and some are available in the paid section (related to the purchase of a YSoft printer). Complete lessons are available for the models, including presentations, models and methodological materials.

Other sources

There are many other sources of 3D model content online. For example:

www.createeducation.com - A platform focused on 3D printing education and technology, offering free models, educational materials and inspiration for teachers.

<https://grabcad.com/library> - A community database sharing thousands of 3D models,

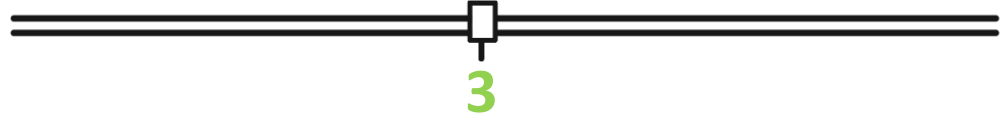
primarily focused on technical and industrial applications.

<https://www.turbosquid.com/> - Database of premium 3D models for professional use, such as film production, advertising or games, with the option to buy and sell.

<https://sketchfab.com/> - Online platform for presenting, sharing and selling interactive 3D models.

<https://www.myminifactory.com/> - A community focused on 3D printing where users can download thousands of print-validated models and share their own creations.

<https://3d.nih.gov/> - Specialized database of 3D models for medical and scientific purposes, focusing on education, research and health applications.



3D Scanners

Another way to obtain 3D objects for printing is from the real world - by scanning. Just as the scanner that comes with most paper printers works, so does the 3D scanner. It's a process that allows you to convert physical objects into digital form. How big the objects are and how accurate is just a matter of price and the size of the scanner.

Types of 3D scanners

There are many types and classifications of 3D scanners, from small handheld scanners to industrial drone scanning. However, we'll take a look at the ones we're more likely to encounter.

Handheld 3D scanners

Portable (handheld) scanners allow the user to move the device freely around the object. They are ideal for scanning larger or hard-to-reach objects.



Handheld scanner Creality. (source: <https://muni.cz/go/1d49b8>)

Stationary scanners

Here, You will need to position the object firmly during the scan. They are used more for precision scanning or scanning smaller objects. By keeping the object and the scanner fixed, the scan is more accurate. It is worth adding, that many cheaper scanners allow both stationary and handheld scanning.

Practical examples

Creating a school museum

Children can scan and digitally archive interesting objects they find, for example, on field trips. They can then use these 3D models to create a virtual school museum that can be shared with others.

Projects with a local focus

In community-focused projects, pupils can scan and preserve digital copies of interesting historical sites or works of art in their local area. These can then be edited and printed.



Demonstration of converting a sculpture to 3D printing via the app (source: <https://blog.prusa3d.com/>)

Personal projects

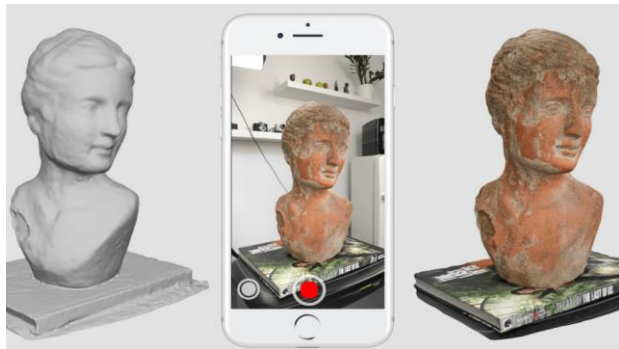
Children can bring in their favourite objects and use scanning to create a digital copy of them. They can then edit, colour and print them as their own unique creation.



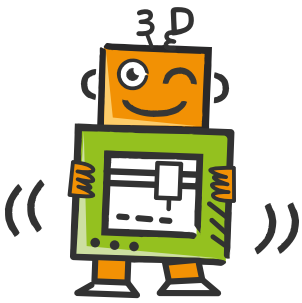
Stationary scanner EniScan - SE

3D Mobile Scanning

Nowdays, modern smartphones can perform a basic 3D scan with the right app. It's simple, affordable and relatively easy to use even in school. However, the quality will vary greatly depending on what phones the pupils have and of course the scanning will not be as accurate as using a scanner.



Sample scanning via mobile app (source: <https://www.sculpteo.com/>)



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3D model creation software

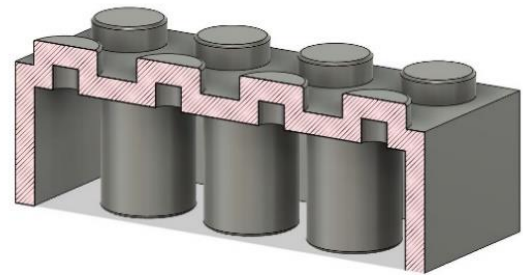
If we want to create a completely new or modify an existing 3D model, we will need 3D modelling software. Importantly, we can also incorporate 3D modelling itself very well into teaching praxis. Let's break down the modelling methods and provide specific and appropriate programs for both creating and teaching.

Solid modelling

Solid modelling works with solids as geometric elements, including their internal structure, so a 3D model has a volume or wall thickness similar to a real object. Modelling is usually done in the exact dimensions of how the solid should be made. A **parametric approach** is most commonly used, where changing parameters (e.g. wall thickness) allows easy editing of the model.

Solid modelling is mainly used by CAD programs (Computer Aided Design), which

are used to design objects for further processing and production. CAD is followed by CAM (Computer Aided Manufacturing) focused on manufacturing and simulation, which includes 3D printing. A volume model can be easily converted to a surface model, but the reverse process is more complex.



Solid model cut

TinkerCAD - www.tinkercad.com

TinkerCAD is a simple online 3D modeling tool designed especially for beginners, allowing easy creation of models for 3D printing or educational purposes. We will

discuss it in more detail in the following chapters.

Fusion 360 is an advanced CAD/CAM/CAE tool that enables complex 3D modeling, design, simulation and manufacturing, and is widely used in engineering, mechanical engineering and product design. But at the same time, it has a simple and intuitive interface, a wealth of tutorials available online and, most importantly, offers free licenses for personal and educational use.

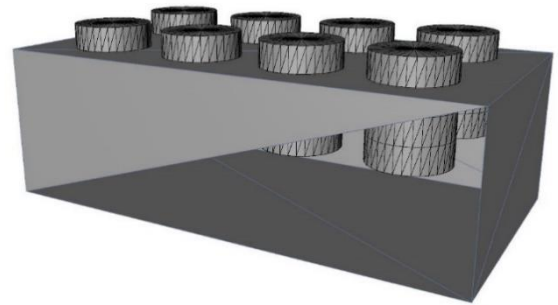
SketchUp is an intuitive 3D modelling software used primarily for architectural, construction and interior design, allowing easy creation and editing of 3D models. It uses a solid but also polygon approach to modelling.

OnShape is a cloud-based CAD software that enables team collaboration for real-time 3D modeling, making it ideal for engineering and product design. It is very popular in the community for 3D printing and available for free.

Polygonal modelling

Polygon (surface) modelling creates models using only surfaces made up of 2D surfaces - polygons, most often triangles. Techniques such as drawing polygons from primitives or 3D curves are used to create models. The resulting object does not have the thickness of a wall and is therefore not realistically manufacturable, but it correctly describes

the external shape. Polygon modelling is used, for example, in computer games and film effects.



Polygon model with one polygon removed.

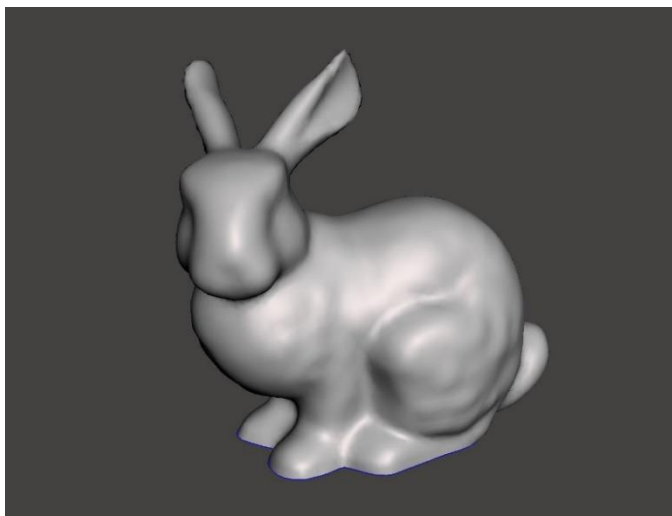
Blender is an open-source 3D software that allows you to model, animate, texture, render and create visual effects. With a wide range of tools and community support, Blender is popular not only for creating animations and games, but also for 3D printing and sculpting.

Cinema 4D is a professional 3D modeling, animation, rendering and visualization software known for its intuitive user interface. It is particularly popular in motion graphics, visual effects and animation, and is widely used in post-production for film, television and advertising. It offers discounted licenses for education.

Sculpting

Sculpting - digital sculpture is a third approach to modeling, focusing on organic shapes and details. The models are created by gradual shaping, similar to hand

sculpting, and the user has the impression of working with a volumetric body even though it is actually an edited polygon mesh. It is used, for example, for figures or natural formations and is common in the game industry and film effects. The resulting models often require retopology (reworking the polygon mesh to reduce the number of polygons) to make them suitable for further use.



Sculpt model of bunny (source: ukázkový soubor Meshmixer)

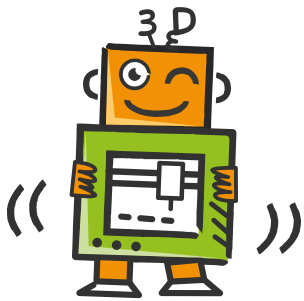
ZBrush - Professional digital sculpting software that is considered the industry standard for detailed modeling and sculpting. A free (feature limited) version is available for beginners and education

ZbrushCoreMini

<https://www.maxon.net/en/zbrushcoremini>

SculptGL is a free online digital sculpting tool that allows you to create and edit 3D models directly in the browser with simple sculpting tools. <https://stephaneginier.com/sculptgl/>

Meshmixer is free software from Autodesk for editing and repairing 3D models, offering tools for sculpting, mesh repair and preparing models for 3D printing.



TinkerCAD - introduction

Have you ever thought of an idea that could be printed but can't be found in any of the databases? Or would you like to model the idea yourself, but you have no experience with 3D modelling, you find the orientation in the tools difficult and you do not know which of the programs to choose, so that even pupils in the first grade can handle it? Then try [TinkerCAD](#) - universal software for beginners and experienced model makers.

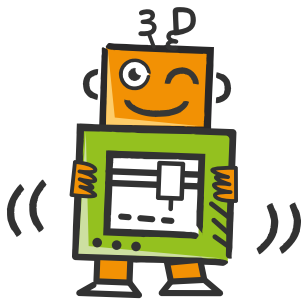
It is a free online tool that can be used across all DIYers who are interested in 3D modelling or are just getting acquainted with 3D graphics. TinkerCAD's environment is very intuitive and can be used by all grades at primary or secondary elementary school level.

To work in the online tool, you need to create an Autodesk account, which can be universally used to log in to all other software from the company, or log in with an

existing account using Google, Apple, Microsoft or Facebook credentials.

Once you have registered and logged in, you can check how you want to use the software in your account settings. In addition, if Teacher Mode is selected, TinkerCAD provides various features that simplify the organization and tracking of student progress with the ability to create [Classes](#), while providing teachers with access to a vast array of [instructional materials](#) and resources.

In addition to 3D modeling, the tool also offers [electrical circuit creation](#) and the ability to [block programming](#) of 3D models. There is also a [Gallery](#) and larger [Projects](#) of models already created by other users, a [Simulation Lab](#), Challenges, [Learning Center](#), or even [complete lesson plans](#). More information can be found directly on the [TinkerCAD website](#).



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TinkerCAD - teacher section

The Teachers' Section in TinkerCAD is designed to support teachers in managing and organizing their educational activities. This tool provides teachers with special access to features and tools that allow them to effectively manage their classrooms and assist students in their learning and development. Along with this, teachers can use this interface to create projects, assign them to students and track their progress.

Setting Teacher mode

In TinkerCAD, teachers can activate Teacher mode to manage and control their classes. To set up this mode, you must first create an account and log in. Once logged in, go to the account settings where you will find the option to switch to the Teacher profile.

Classes - additional section for teachers

What is displayed when I switch to Teacher mode?

When you activate Teacher mode, you will have access to a number of specific features and tools that are not available in the regular user interface. You can manage your own classes, add and remove students, create and assign projects, and track student progress.

How to set up classes:

Setting up Classes in Teacher mode is possible in several steps:

1. Go to the Classes section in the top panel, or click Classes in the left sidebar.
2. Click the Create New Class button.

3. Fill in the necessary information such as Class Name, select Age and Subject from the drop-down box, choose Safe Class Mode (whether students can view and delete posted drafts and work "privately" on their project), and confirm with the Create Class button.
4. After creating a class, you can add students either manually or by direct import from the student list.
5. To join the class, you can share a link to the class with the class code, through which the students will join the class themselves under a given nickname or email.

Thanks to Classrooms, the teacher can also create and manage assigned projects within the classroom in one place, monitor student progress and check their activity while working on the assignment through the dashboard, invite colleagues to the created classroom for collaboration, or share and import student projects at the same time through the Google Classroom connection.

Lesson plans:

TinkerCAD offers teachers, among other things, the possibility to get structured Lesson Plans that facilitate the preparation and implementation of digital design lessons and can be found in the Materials section from the top panel. In these lesson plans, detailed instructions, objectives, lesson

materials and links to additional resources or materials can be found. At the same time, teachers can share their lesson plans with other colleagues and tailor them to the specific needs of their classrooms.

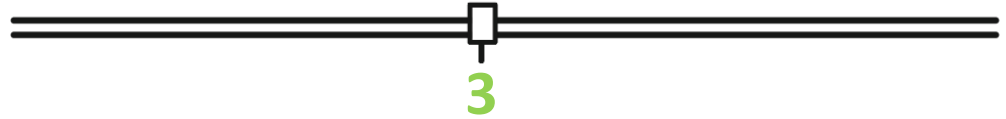
TinkerCAD provides detailed tutorials for all these tools, which can be found in the links provided and also on the official [YouTube channel](#).

Useful links:

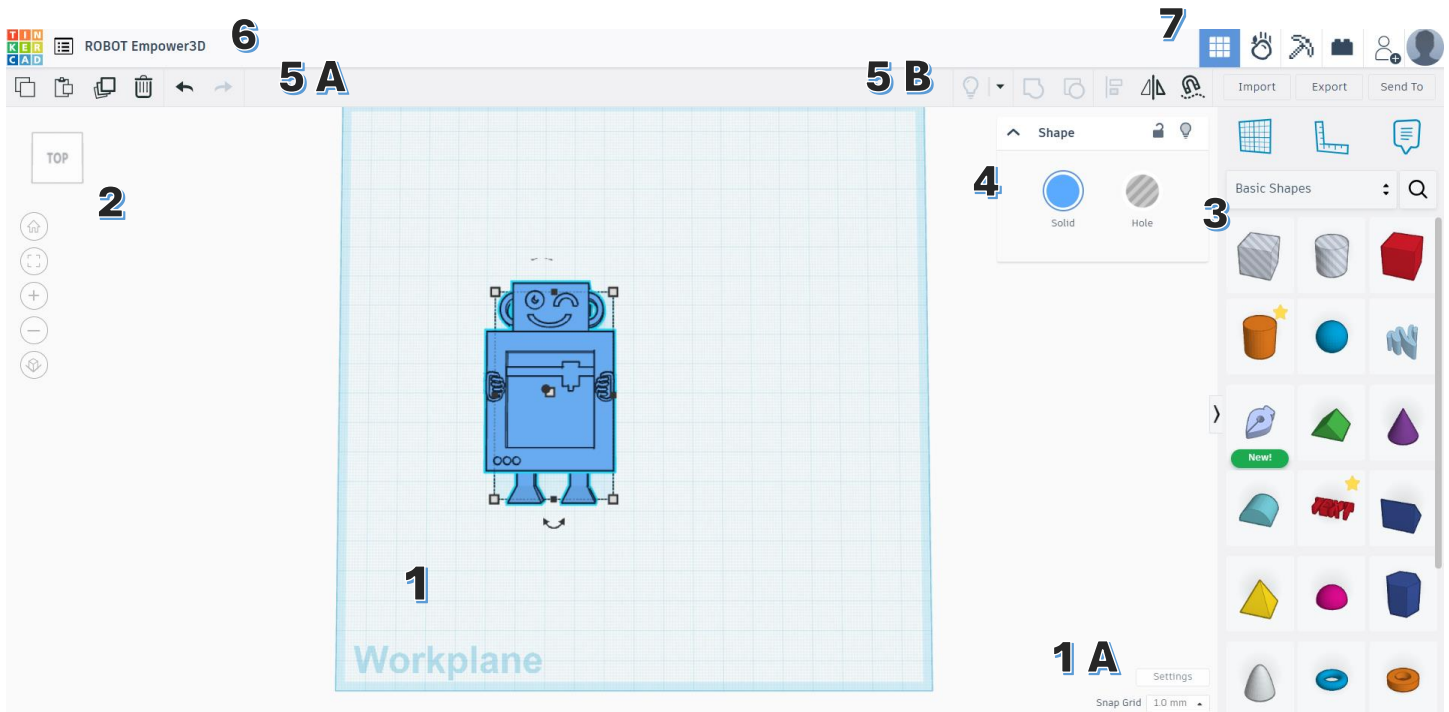
[Official Teacher's Guide to TinkerCAD Classes](#)

[TinkerCAD lesson plans](#)

[Co-teaching in TinkerCAD classroom](#)



TinkerCAD - Essential Workspace Interface



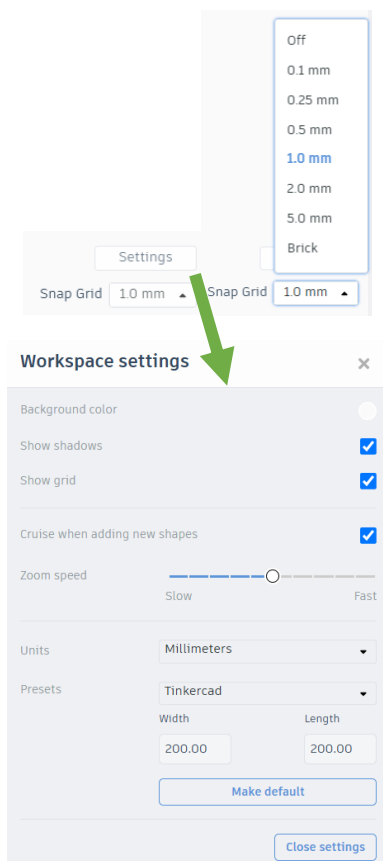
A basic view of the TinkerCAD modeling interface. 1 - Workspace; 2 - Controls for orientation in the space and on the desktop; 3 - Sidebar with objects; 4 - Dialog box of currently selected objects; 5AB - Panel with functions and tools; 6 - Project name; 7 - Additional options for displaying the workspace (3D design, Sim Lab, Blocks, Bricks) and the possibility of sharing to collaborate on the model.

In this chapter, together we will look at the basic layout of the TinkerCAD* modeling interface, which allows for easy project management and navigation, making modeling intuitive and efficient.

1 - Work area

The TinkerCAD workspace is the central part of the interface where you can create and edit your own 3D models. All objects can be placed, manipulated and combined with

each other and modified using tools. The workspace can be customised to suit your modelling needs, using the *Workspace Settings* (1A - found in the bottom right corner of the workspace), where you can play with the shape of the workspace, the speed of movement when working with shapes, the size and type of the workspace (the default TinkerCAD workspace, or the workspace of a specific 3D printer or CNC machine). You can also adjust the step size, which can be useful when accurately measuring the distance to an object, or aligning objects to an edge.



Workspace settings and step size.

2 – Controls

On the left side of the workspace we can find basic controls that allow us to rotate the object freely in space using the Rotation Cube and switch between 2D and 3D views in terms of individual views by clicking on the marked area of the cube. There is also a Default View button that centers the view on the entire workspace, a Fit View to Selected Shapes (F) option that zooms the camera in on the selected object, Zoom In (+) and Zoom Out (-) buttons, and the ability to switch between Flat and 3D views when modeling.

3 – Object panel

On the right side of the workspace you can find a panel with the default 3D objects. You can choose between Basic Shapes (such as cube, cylinder, sphere and others) or choose from a menu of special objects - for example, from Building Elements and Scenes, to Electronics, Creatures and Characters, to Shape Generator, where you can have ready-made models generated or customized, including the generation of a specific shape for a country model or a 3D QR code. The basic and some special shapes can be modified without any problem, the others, especially the more complex objects (for example some models like Laptop or Instax photos in the Everyday Objects section) cannot be resized (this can be done

in other software or after exporting them directly before printing in Slicer). The Magnifier tool is used for quick searches between shapes. For optimal results it is advisable to enter keywords in English.

Above these shapes we also find three icons representing tools such as the Workspace, Ruler and Notes.

4 – Type of object

When selecting an object and placing it on the workspace, it is possible to choose whether the object will behave as a Solid (solid object) or as a Hole (hollow object for the possibility of creating a cutout). This way of working with objects is explained more in a separate chapter. In the dialog box, you can select and modify other property options according to the type of the selected object - from adding text, to adjusting the thickness, spacing of parts, number of segments in the object, etc. You can also choose the color of the object, which is often useful when working on multiple parts of the model at the same time. This improves the orientation between them, while also telling us which parts are still separate and which, on the other hand, have been unified in color when merged together**. It is also possible to lock objects to prevent further (and unwanted) modifications or to hide the object completely.

5 – Top bar with functions

In the top bar you can find various functions and tools that can be used to edit the model - on the left side of the top bar you can work with functions such as Copy (CTRL+C), Paste (CTRL+V), Duplicate and Repeat (CTRL+D), Delete and buttons with Back (CTRL+Z) and Redo (CTRL+Y) steps.

On the right side of the top bar, there are tools such as the ability to merge objects using Show All (CTRL+Shift+H) (shows annotations and hidden shapes), Grouping (CTRL+G), ungroup objects using Ungroup (CTRL+Shift+G), and the ability to Align (L), Mirror (M), or snap objects to a given part of another object's surface using Layer (C). In addition to these functions, the Import, Export and Send To buttons can also be found to the right of these functions for importing and exporting the model with the possibility of sharing and collaborating on the project with another user, even in real time.

6 – Project name

Above these functions you can find a button with the TinkerCAD logo in the upper left edge to return to the Control Panel, a button with the Last Designs to which you can switch, and an automatically generated Project Name - this is a general designation by TinkerCAD in order to distinguish individual projects, however, for better

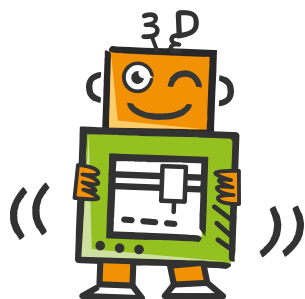
orientation and overview of the students themselves, it is convenient to name the design according to their own needs - for example, the name of the student + class, the name of the model itself, etc.

7 – Design view and sharing options

In the last section, located in the upper right corner above the function bar, you can find buttons to switch between the 3D design views in its different forms - there is a 3D design button with the default workspace, then Sim Lab, Blocks, Bricks, a button with the option to Invite users to design with you and an icon with an avatar of your own profile.

* For better orientation, the individual parts of the modelling area are marked with numbers in the picture.

** Color unification of multiple objects together may not always work - this is especially true for special complex shapes, which usually retain their original colors even after grouping.



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TinkerCAD - Description and use of objects and tools

V této kapitole si představíme jednotlivé nástroje a popis práce s objekty v rámci 3D modelování v prostředí TinkerCAD. Jejich přímé použití si vysvětlíme v další kapitole a také samostatně na modelu ve videonávodu k tvorbě EMPOWER3D robota a příslušném pracovním listě.

Start of the 3D design

To start direct modelling, you need to log in (or register) to the TinkerCAD environment. After logging in, you will be taken to the default interface - the so-called Control Panel, where you can find not only the 3D design, but also Design (with all 3D projects), Collections, Tutorials and Challenges. In the case of teacher mode, the Classes section is also displayed here.

To create a 3D design, click the **+ Create** button in the upper right corner of the Default page of the control panel and select **3D Design** from the drop-down box. This will

then display the workspace* where we can start modelling.

Objects and tools in TinkerCAD

To start modelling, it's a good idea to familiarize yourself with the default options TinkerCAD offers - these include various tools and a sidebar with a library of individual objects.

Basic shapes and tools

The design can be based on basic shapes such as Block (Cube), Sphere, Cylinder, Cone, various types of prisms, Hemisphere, Half cylinder, Tube, Star, Heart and other basic geometric shapes that can be combined and modified. You can also find a shape for creating Text and a Scribble tool for free drawing options.

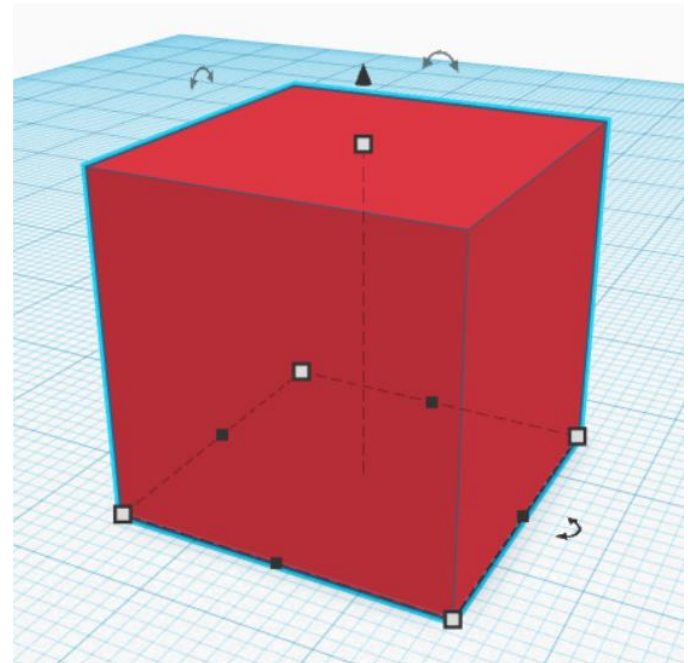
In addition to basic shapes, the library includes ready-made models that can be inserted into the design and further modified according to your needs. It is also possible to search among these shapes to quickly find a specific model for the needs of a given design.

Individual shapes can have their Properties modified before the modelling starts, which can be used to affect, for example, the number of walls and thus the shape, to modify the dimensions, or to change the colour and choose whether it is a solid or a hole, which can be used to cut the shape into another object without using specific tools to modify it.

In addition to editing properties, several basic functions and tools can be used to work with objects, including Object Shift (left, right, up, down) and Object Rotation (rotation) in axes, Scaling (changing object dimensions) using bars, and Working with Cartes for precise dimensioning when modeling.

Objects can also be grouped together using the Group tool and separated from each other using Ungroup. They can be aligned to each other according to the edge of one of the objects, Mirrored in all axes, for example when creating paired shapes, Copied to insert one or more copies of the object anywhere in space at the same time,

Duplicated to place the copy next to the original, etc.



The default basic tools for working with an object include pan, rotate, and scale the shape.

Additional features

Special shapes with access to a wide range of pre-formed components such as joints, gears, electronic components and more. In addition, it simultaneously offers advanced Shape Generators that allow you to create custom objects using scripts or by selecting from a library of predefined shapes.

In addition to this feature, the library also offers elements for Sim Lab, which are designed to simulate the motion and physical properties of objects to check their functionality.

It is possible to use the Import model from a file or database into the design and further

modify it as well as Export the finished model in STL, OBJ or SVG format for use in other modelling software or for preparation in Slicer for subsequent 3D printing.

*The whole TinkerCAD workspace and its layout can be found in a separate chapter.



TinkerCAD - Creating a model from a primitive

In the next chapter, we will explore modeling from primitives, or basic geometric shapes such as cubes, spheres, cylinders, or cones, which serve as building blocks for more complex models. In TinkerCAD, these simple shapes are used as starting points that can be freely combined, modified and edited using the tools available in the program. When creating a model from the default objects, it is useful to work with the various properties of the objects, which can be further utilized when modifying them using various tools. In this way, simple shapes can be used to create complex and sophisticated models, which can be modelled even by pupils at primary school.

Solid object vs. Hole

In TinkerCAD, Solids are basic objects that have a specific shape and volume, such as a block or sphere. These objects can be further modified and combined to create more

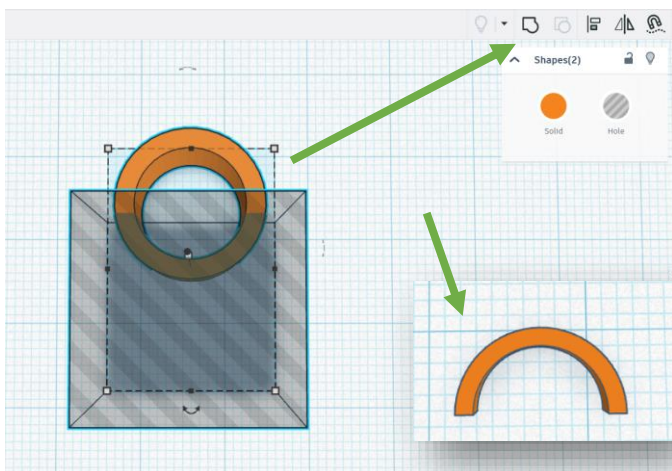
complex structures. A solid is a solid object that is used as a building block for models.

A Hole is a TinkerCAD property designation for a special object type that is used to create empty spaces or holes inside other solids and can be applied when using the Group tool in conjunction with another solid. A Hole has no volume of its own, but when combined with a Solid it creates a cavity or cutout inside the solid. Holes can be shaped in many different ways, just like Solids, and when used correctly they allow the creation of detailed and functional models such as keychains, wheels, figures, toys, etc.

Group

Group is a tool that allows you to combine multiple objects into a single unit. In TinkerCAD this process is very simple and intuitive. Just select the objects you want to group and use the appropriate function in the toolbar. Grouping is useful for creating

complex models because it allows you to manipulate multiple objects as a single unit. This means you can easily move, rotate, or resize a group of objects without having to edit each individual object separately. In addition, grouping makes it easier to organize and manage models, which is especially useful when working on larger projects with many components.

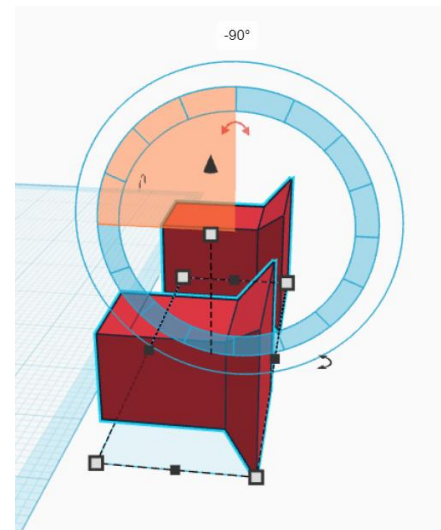


Grouping Body and Hole to create a blinking robot eye.

add and edit dimensions using the mouse and tools available in the user interface.

Rotation of model

Model rotation is another key tool when working in TinkerCAD. It allows you to rotate objects around different axes (X, Y, Z), which is necessary to achieve the desired shape and orientation of the model. Rotation is useful, for example, when placing parts in the correct position or when creating symmetrical structures. In TinkerCAD, rotation can be performed by using interactive handles that appear around the selected object or by specifying precise rotation angles in the corresponding fields. Object rotation is intuitive and allows for quick and easy adjustments to models as needed.



Leg rotation of the robot to settle on the underside of the torso.

Dimensioning and model rotation

Dimensioning

Dimensioning is a process that allows you to accurately determine the dimensions of objects in TinkerCAD. Using the dimensioning tools, you can measure and adjust the lengths, widths, heights, and other dimensions of individual objects or groups of objects. Dimensioning is important to ensure accuracy and consistency when creating models, especially when parts need to fit together exactly or meet certain specifications. In TinkerCAD, you can easily

Text

The Text tool in TinkerCAD is for adding text elements to models. You can create lettering, markers, labels, or any other text objects you need for your project. Text can come in a variety of fonts, sizes, and styles, allowing you to personalize and customize the look of your models. In addition, you can combine text with other objects, for example, add lettering to the surface of a cube or create an embossed font. The text tool is intuitive and easy to use, just type the desired text, edit its parameters and place it in the right place in the model.

Properties of shapes

When working with these shapes, it is important to know their properties and how to set them up to achieve the desired result. In TinkerCAD we can adjust the size, shape, color or transparency of the objects. Each shape has specific parameters that can be easily changed using the editing tools - for example, a cube can be transformed into a sphere by changing its dimensions, while a sphere can be enlarged or reduced in size while retaining its spherical shape. TinkerCAD's tools also allow you to add various textures and surface treatments to give a more realistic appearance to an object.

Other editing options

Precise alignment

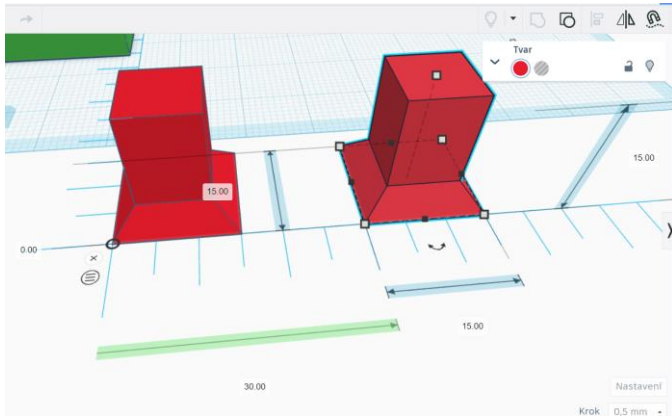
In addition to these modelling methods, it is also possible to place the objects exactly in position, relative to each other, or - the Align tool is used for this purpose.

Align allows you to precisely position and align objects according to certain criteria, either relative to each other or to a specific axis, such as edges or center. This tool can be applied when selecting objects to be aligned that are placed on or near the surface, then after applying the function, the desired position is set.

Ruler, Work Plane and Notes

Ruler

A ruler is a tool that allows you to accurately measure and place objects in a model design. Using the ruler, you can easily find the distances between objects, determine their size and check their position. The ruler is ideal for creating detailed and precise models where the accuracy of individual dimensions and correct positioning is important.



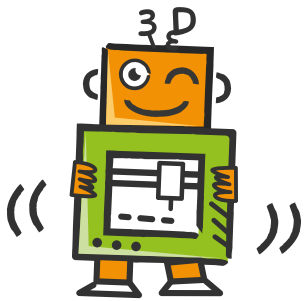
Precise placement of robot legs with their mutual spacing

Work plane

The work plane is used to specify the plane on which to work. It allows you to place objects on a specific level or surface of the model. This tool is especially useful when creating more complex designs where you need to work with different levels and surface shapes of the model surface.

Notes

Notes is a tool for adding text comments directly to the model. They allow you to mark important parts of the model, explain features or provide instructions for further work. Notes are a convenient means of communicating between classmates or keeping track of the steps involved in creating a model.



TinkerCAD - Free drawing and shared modelling options

When modelling in TinkerCAD, it's possible to come across some interesting tweaks that can help students and make modelling more complex shapes more efficient - whether it's a specific shape or multiple hands are needed, TinkerCAD offers both solutions.

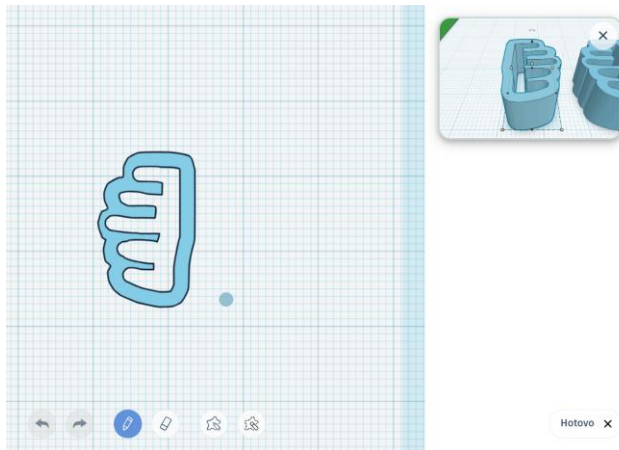
Scribble Tool

This tool allows you to freely draw and create your own shapes directly on the desktop. Use the mouse or touch pen to draw arbitrary lines and shapes that are automatically converted into 3D objects.

The tool can be activated by selecting a Scribble shape from the basic shapes menu. This activates the free drawing function. Using the mouse or the touch pen, you can start drawing on the designated drawing surface and create curves to your liking.

While drawing, the individual strokes are immediately displayed in the Preview in the upper right corner next to the drawing area (the Preview can be hidden and displayed back at any time). In case of a wrong stroke, the point or a larger part can be deleted, or the entire drawing can be removed.

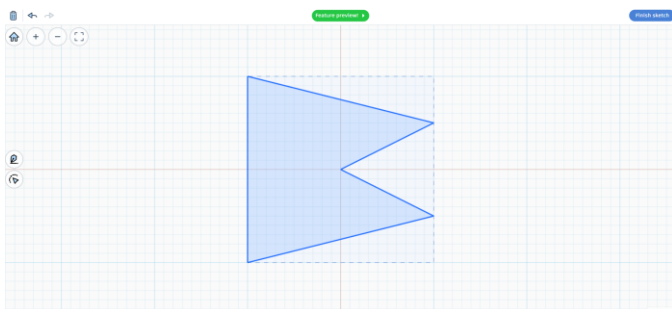
Once the sketch is complete, the Done button can be used to return to the project area where the drawing can be manipulated as a 3D object. You can always return to editing the sketch by clicking on the 3D shape. These 3D drawings can be saved in the Custom Shapes library and used as finished objects in modelling.



Working in Scribble - creating a robot hand.

Sketch tool

While it is possible to create completely freehand drawings in Scribble, with Sketch it is possible to work with precise sketches using vector curves thanks to predefined utilities such as Line, Bezier curve and grid work. It can be used to create geometric and engineering objects that require high precision. The Sketch feature allows users to start with simple 2D drawings that can then be extruded into 3D shapes, making it easy to work with complex designs.



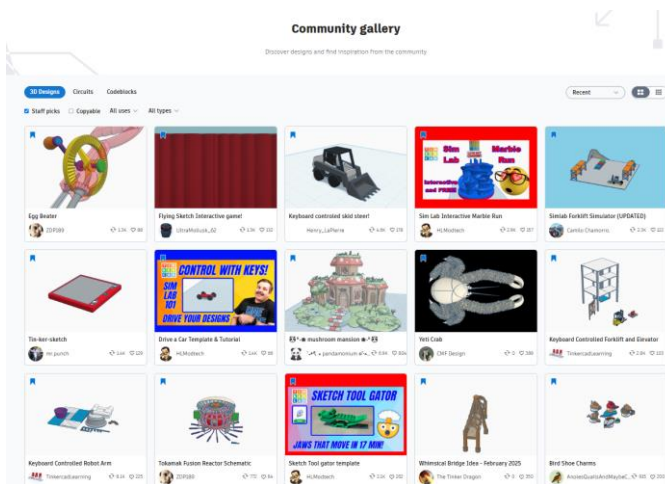
Working with Sketch.

Direct collaboration on the model and sharing options

Collaborating on a model in TinkerCAD is very intuitive and allows users to share their projects with other team members. If students are working on a complex design, it is possible to invite other classmates to join their project and collaborate on it in real time. This feature is particularly useful when working collectively on large-scale models, where everyone can contribute their knowledge and skills.

In addition to sharing a project with classmates in real time, TinkerCAD also offers the ability to share your creations through an open Project Gallery where you can upload your creations and make them available to the entire TinkerCAD community.

It is also possible to find inspiration in the work of other users and modify these creations according to your needs. Thanks to these possibilities, the classroom work can be enriched with an element of dynamic collaboration, where students can freely share their ideas with each other and thus influence each other.



The gallery of Tinkercad users' designs offers a plethora of ideas that you can use for your own needs and work with further.

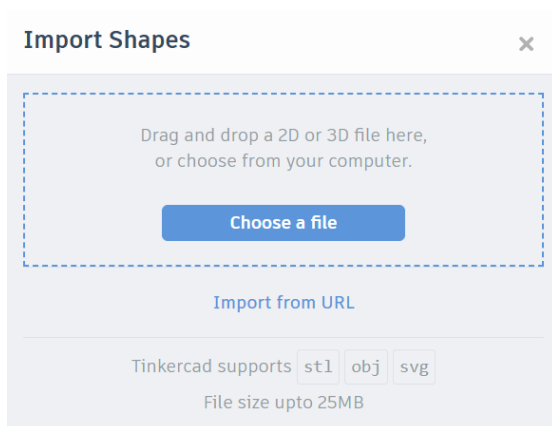


TinkerCAD – Import and Export of models

In this chapter we will look together at the possibilities of importing a model into TinkerCAD and also at the possibilities of exporting the resulting project.

Model import

If you already have a finished model and you would like to modify it in TinkerCAD or add it to the object you are currently modelling, you can use the Import function to do this.



You can import in two ways - from a file on your computer, or by downloading the model from a website - for example, a database.

Clicking the Import button in the top right corner of the screen will open a dialog box with the option to insert the file. There are then two ways to insert objects:

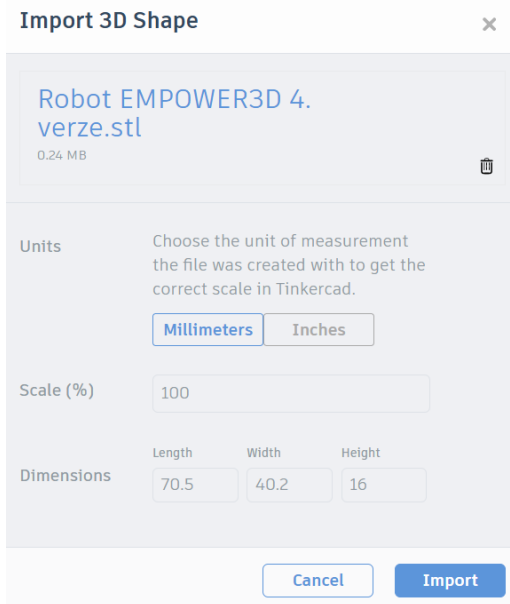
1. Inserting a model directly from a file on the computer - just select the model in STL format from the folder (you can also select a model in OBJ and SVG format), then confirm the selection, set the parameters and let the model be imported into the TinkerCAD workspace.

Or:

2. Inserting a model directly from a web page (e.g. from the databases like [Thingiverse](#), [Printables](#), etc.) - here it is possible to choose to import an already finished model directly from the website by inserting the copied URL address of the model, which is then uploaded to the TinkerCAD

workspace after editing the parameters.

When inserting models, you can simultaneously set the scale in %, units (mm or inches) and model size.



When inserting a model, it is also possible to set parameters.

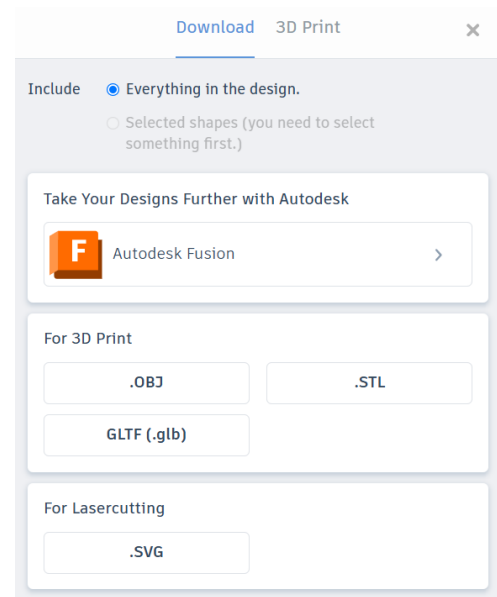
Model export

In the case of a finished model, it is possible to export the model from Tinkercad to another software and work with it further, or to prepare it in Slicer for 3D printing. The model can be downloaded using the Export button next to Import in the upper right corner of the workspace..

After clicking, a dialog box appears, in which it is possible to choose what we want to download from the design (either everything or the selected shape), as well as the output format (the most common is STL, but you

can also choose OBJ and GLTF, or also SVG format for subsequent work with the laser). The choice is then confirmed and the prepared file can be saved to the computer and further used for 3D printing applications.

Tinkercad also offers the possibility to send the finished design directly to the cloud of one of the offered 3D printers or to the Fusion 360 software. Using the Send To button, located next to Export, it is possible to download a preview image of the current design, or share the design using [Google Classroom](#), or send it directly to one of the databases and portals offered such as [MyMiniFactory](#), Thingiverse, etc.



When downloading, you can choose the output format and download the model to your computer, or have it sent to your cloud 3D printer, database, Google Classroom or Fusion 360 software.



Slicer - model preparation for 3D printing

Before printing, the 3D model needs to be "sliced" into layers using a process called slicing, which generates instructions - **g-code** - for the printer. This process is done in a program called a **slicer** (e.g. Cura, PrusaSlicer, Simplify3D). In the slicer, the model can be modified, rotated, resized or divided into parts for easier printing. Key settings include **layer height**, infill, material, and print head and bed temperatures. Slicer also allows you to set **support** for printing overhanging parts of the model. Most slicers offer pre-made **profiles** for printers and materials, which optimizes print settings.

G-code is the file into which the 3D model is converted in the slicer, and contains instructions for moving the extruder and printer bed. These instructions specify the X, Y and Z axis movements of the print head, layer by layer as it prints. The G-code also includes settings such as print speed, fan speed, or parameters for the first layer.

While the stl 3D model can be used freely, the g-code is generated for a specific printer and is therefore not generally portable.

There are various slicers used in the 3D printing community that vary in functionality and compatibility with a wide range of printers. Some of the best known include :

Cura - A simple but very powerful slicer developed by Ultimaker, compatible with a wide range of printers.

Simplify3D - A paid slicer with advanced features and great support for different printers and materials.

Slic3r - An open slicer that has served as the basis for many other slicers (including PrusaSlicer).

PrusaSlicer - A slicer from Prusa Research, popular for its flexibility and compatibility with 3D printers. In this slicer we will further demonstrate the slicing process.



Slicer – import and basic navigation in the interface

When running the slicer for the first time, it is necessary to select the printer (or printers) to work with so that the output g-code is compatible (the screenshots in the following text are from PrusaSlicer 2-9-0-rc1 and may differ slightly for other versions, we recommend to always use the current version of the slicer).



Printer selection in slicer

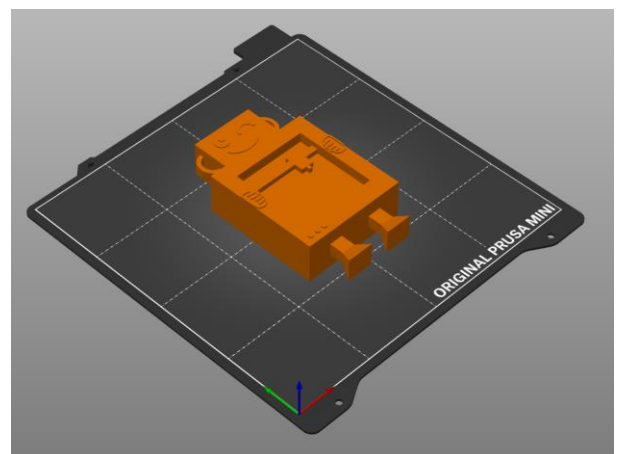
Model Import

To insert a model, use the first option in the top menu (Ctrl+I):



Main top menu of the slicer

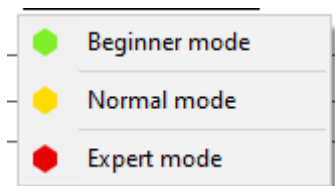
The model appears on the workspace displaying the print bed of the preset printer, and we can further manipulate and set the print.



Model imported into slicer

Overview of the slicer environment

The slicer interface varies depending on the mode you have set (top right corner of the application). Select advanced or expert mode to display hidden controls (in the following text, we use expert mode).



Volba režimu sliceru

The other items in this menu are for basic model work, the main ones being :

- Delete Model and Delete All
- Arrange on bed, which automatically places one or more models on the print bed
- Copy and Paste
- Add Instance - inserts another instance of the model to print multiple copies at the same time
- Split the model into parts (if possible)

The second main menu can be found on the left:



Left main menu of the slicer

It contains a number of tools used for further manipulation of the model, mainly:

- Tools for shifting, resizing and rotation - every time you select a tool, the axes for this manipulation will be displayed on the model
- Placing a surface on the pad - allows you to select any surface on the model and use this surface to place the model on the printing pad
- Cutting the model to divide it into parts
- Advanced tools for painting supports and more.

The last of the controls in the main viewport is in the bottom left corner to switch between the 3D editor and the slicer view



Switching the view in the slicer

When switching to Preview, the model is sliced and the layers are displayed according to the slicing settings.

Manipulation with the object

In addition to the tools in the left menu, it is convenient to use the numeric input in the lower right part of the slicer to manipulate the object:

Object manipulation

World coordinates

X

Y

Z

Position:

90

90

8

mm

Rotate (relative):

0

0

0

°

Scale factors:

100

100

100

%

Size [World]:

40.2

70.5

16

mm

☐ Inches

Info

Size:

40.20 x 70.50 x 16.00

Volume:

30073.24

Facets:

5076 (1 shell)

No errors detected

Manipulation with the object

We can adjust the position of the model, its rotation and also the scale. The size is probably one of the most frequently adjusted parameters before printing and we can adjust it not only in mm but also in percentage.

Under this menu we can find some basic info about the object as such.

Above this menu there is a list of objects inserted into the slicer. Individual objects can be hidden or further edited via the right mouse button.



Slicer – setting print parameters in the slicer

Slicer has many settings and options. However, for normal printing we can get by with a few basic but important settings, which we will discuss in more detail in this chapter. All the key settings can be found in the top right of Slicer.

Print settings:

0.20mm STRUCTURAL

Filament:

Generic PLA

Printer:

Original Prusa MINI & MINI+ Input Shaper

Supports: None

Infill: 15% Brim: ☐

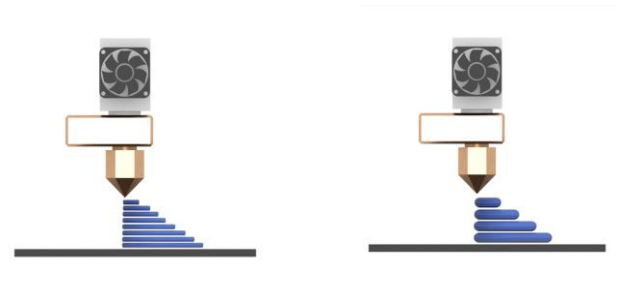
Print settings

You can access more detailed settings via the gear wheel on the right side of each option, we will discuss some of the detailed and advanced settings later.

Layer height

One of the main parameters is found under print settings, and that is the height of the

print layer. Depending on the printer, it is possible to set 0.1 - 0.2mm normally, but these options can be further adjusted to smaller or larger heights.



Layer height

With a height of 0.1mm compared to 0.2mm, the printing time will be approximately twice as long because twice as many layers will be needed for the same size model. However, smaller layers for jagged objects will improve the quality of the print itself.

Filament

When slicing, the filament is important mainly in terms of setting the working

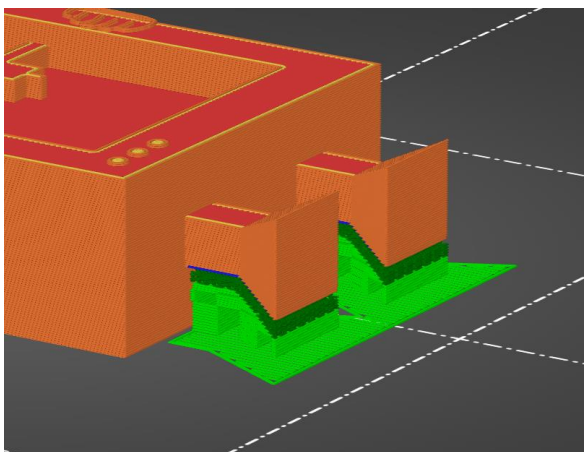
temperatures. In the menu we can find selected filaments, but also "generic" PLA, PETG etc. with basic (and mostly universally applicable) temperature settings. In case of printing problems, however, we can adjust the values in the slicer or directly on the printer.

Printer

Setting up the correct printer is crucial in all printing parameters and g-code prepared for a different printer than the one you will print on will not work optimally (or at all). From the menu we can select from the predefined printers or add another printer.

Supports

Because the printer applies one layer on top of the other, it is often necessary to turn on the supports in case of overhangs or bridging. The supports are auxiliary printing structures that support parts of the model (robot legs in the figure below).



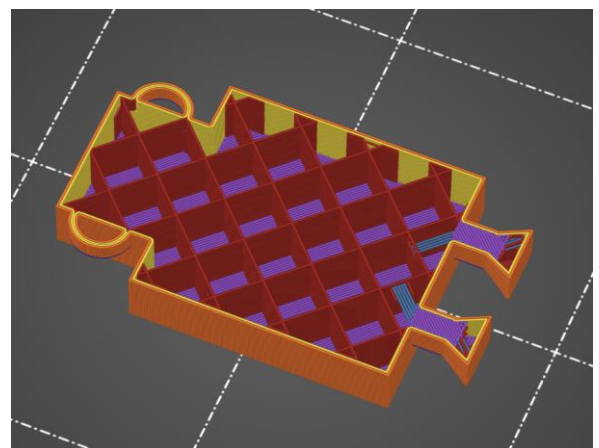
Supports turned on

If they are enabled only on the print bed, they are generated only between the bed and the object, or if "everywhere" is selected, they will also be generated between two parts of the model. The last option is just forced supports, which can be specifically set with the support painting tool in the left tool menu. The supports are generated based on the limit angle setting. This and other settings can be further adjusted in the advanced options via the gear icon.



Infill

0 % - 100 % are the infill setting options. Normally it is not necessary to fill the entire printout with material. For faster printing and less material consumption, a setting of around 10 - 20% is usually sufficient. However, when printing stressed parts, it is advisable to increase the infill.

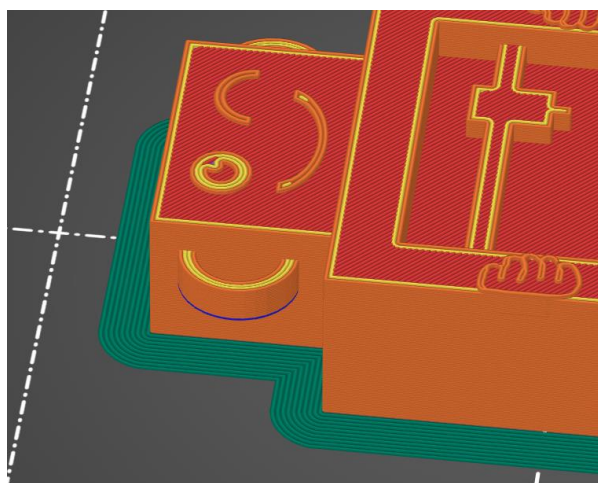


10% infill

In the advanced infill settings (gear icon) we can also select different infill patterns.

Brim

The last of the basic parameters is the brim. Enabling this option will print several extra perimeter layers of the model on the first layer. The reason for this is to improve adhesion to the bed and increase the area of contact between the object and the substrate. These parts can then be easily separated from the model after printing. The brim makes sense especially if the contact area with the bed is small.



Brim turned on around the model

Slicing and g-code export

After setting all the parameters, you need to perform the actual slicing. To do this, use the button on the bottom right. Depending on the complexity of the model and the settings, the slicing process may take some time and may also result in warning or error messages (e.g. the model is not touching the bed, etc.). In this case, the model or the settings need to be modified.

Slice now

After correct slicing on the bottom right we can see summary information about filament consumption and printing time.

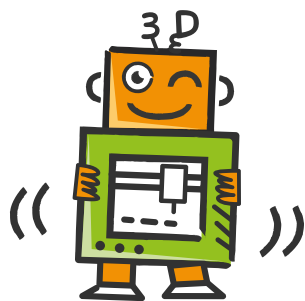
Sliced Info

Used Filament (g)	13.77
Used Filament (m)	4.62
Used Filament (mm ³)	11103.44
Cost	0.35
Estimated printing time:	
- normal mode	39m
- stealth mode	41m

Final step of slicing is to export the g-code.

Export G-code

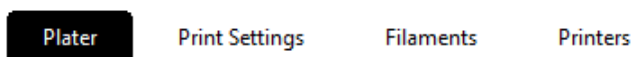
The g-code is saved (e.g. on a flash drive) and can then be started on the printer.



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Slicer – selected advanced settings

Even though for most common prints we can make do with the basic parameters described in the previous section, slicer offers a large number of advanced and detailed options (especially in the expert mode switchable in the upper right corner). Access to advanced settings can be found at the top of the application via the "Print Settings", "Filaments" and "Printers" menu tabs.



Below are just a **selection of the settings** for the more commonly used options. A complete overview of PrusaSlicer can be found on the manufacturer's website:

<https://help.prusa3d.com/article/general-info 1910>

<https://help.prusa3d.com/category/prusaslicer 204>

Print settings

The print settings menu consists of several submenus in the left column:

Layers and perimeters

- Layer height - detailed adjustable height of one print layer
- Vertical walls - setting the number of perimeters, i.e. the thickness of the object's wall before the infill is formed. In combination with the infill, it determines the strength of the object
- Horizontal walls - determines the number of solid layers on the bottom and top of the object

Infill

- Infill - the density of the infill and its pattern setting will affect the strength

of the object, but also the printing speed and filament consumption.

- Ironing - smoothing the surface of the object to improve the appearance of the upper layers of the object.

Skirt and Brim

- Brim - setting auxiliary print loops around the object, unlike the skirt, the loops are typically at a distance from the object to help protect the first layers, but the brim can also have height and form a protective shield around the entire object, e.g. against airflow and peeling, twisting layers.
- Skirt - the location and size of the skirt around the object on the first layer to improve adhesion to the bed.

Supports

- Supports - apart from turning supports on and off, the basic parameter is the limit angle for creating supports, which determines at what slope supports for overhangs are still generated or not generated.
- Raft - prints an additional support raft of the set layer height under the entire object including supports.
- Options for supports and raft - by adjusting the style, Z-axis spacing, pattern, spacing, etc., we can significantly affect the quality of the

supports, their adhesion to the object, and therefore the ease of removing the supports after printing is complete, as well as the speed of printing the supports.

- Organic supports - when the Style is set to "Organic", supports are generated as thin "branches" that split. They are useful for faster printing, easier removal, and can support parts where normal supports would have to hold onto other parts of the printed object.

Speed

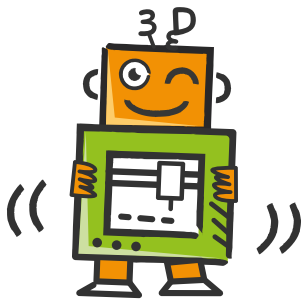
- Printer motion speeds - when printing different parts, the speed of the movement is very important for the speed of the whole print. Here we can set all the options in great detail. In general, however, slower movements generate higher quality print.

Filaments

Use the settings in the **Filaments** submenu to set the filaments for printing in detail. The main parameter is the temperature of the nozzle and the bed for the actual printing. At the same time it is also possible to adjust the **Cooling**, i.e. switching on, off and speed of the print fan. We can also specify the cost of the filament price, so that when slicing the print price is calculated correctly.

Printers

The last setting menu is closely related to the printer preset. We can modify the printer firmware type, print dimensions and g-code type, including entering our own g-code for printing. In general, it is not necessary to interfere too much with these options. If the printer supports it, it is a good idea to enable binary g-code for faster generation and smaller file sizes.



3D printer print preparation and printing

If we have generated g-code in the slicer, we can start printing. Typically (depending on the type of printer and its connection), we save the g-code in the slicer to a flash drive (or sd card) and connect it to the printer when it is on. In the following text we will briefly go through the steps before and during printing.

Filament

Inserting or replacing the filament is one of the main steps before starting to print. The printer should have the type of filament that matches the settings in the slicer. To remove/insert or replace filament, follow the instructions in the printer menu. Before inserting and feeding the filament, it is advisable to check the amount of filament (especially if the printer does not have a filament sensor) to ensure that it is sufficient for the entire desired print. When inserting the filament into the feeder, it is advisable to

cut the end of the filament diagonally with pliers so that it can be more easily fed into the printer. Also, when feeding, make sure that the filament is not crossed somewhere and that the filament cannot get tangled during printing and that the filament can be unwound well when feeding from the spool.

Print bed

First of all, of course, we remove all previous prints, including their residues, from the printing pad/bed/plate. The printing bed plate must be correctly seated. It is advisable to degrease the printing plate using isopropyl alcohol before starting the print so that the print adheres well to the substrate. If we anticipate problems with adhesion to the bed, we can apply a thin layer of office adhesive to the bed.

Starting the print

If the filament and the print bed are ready, we can start printing by selecting the g-code file. Before printing, check the file name (or preview) for accuracy and start printing. The printer will perform a pre-calibration and warm-up of the print head and bed and then start printing.

First layer

The adhesion of the first layer to the bed plate is crucial to the entire print, so it is advisable to check the first layer for any length of time and address adhesion problems early. We can stop printing with minimal loss of time and material, recalibrate the height of the first layer on the printer and start printing again, apply adhesive, etc.

Printing progress

As print times can normally be in the hours or more it is not possible to constantly check the print, however it is still advisable to check occasionally if possible. The sooner we stop a faulty print, the less time and material we lose, but more importantly, we prevent further problems. For example, if the print comes off the bed and the printer continues to print in the air, there is a risk of filament sticking to the extruder, nozzle and electronics, damaging parts or requiring

complicated filament removal and cleaning of the extruder. The printing itself should take place in a room with no airflow and lower humidity. Overall, a higher room temperature is more appropriate. If the printer does not have an enclosure, any fluctuations in temperature and airflow can cause printing problems.

Ending the print

Printing will terminate itself after the g-code instructions are completed. It is advisable to wait for the print to cool down before removing it from the pad, to avoid twisting during removal, and also to make the print easier to remove from the bed overall. With a flexible printing bed plate, bending it slightly to either side will make it easier to peel the print off the backing. You can also use a spatula (preferably a plastic one to avoid scratching the plate).



3D printing postprocessing

In some cases, a successful print is the final result, but in others we can (or need) to proceed to further processing of the print. The reasons can vary from purely design reasons to purely functional reasons. Let's now briefly discuss the basic options for further processing.

Connecting parts of the print

There are several reasons for joining a model (or its parts):

- Printing parts with different colours (materials)
- Printing a model that is too large, divided into several parts
- Printing models that are supposed to be "disassembled" (e.g. screw-nut)

It is often advisable to model and prepare the disassembled joints directly before

printing, such as various connecting pins, latches, etc. For non-detachable joints, gluing is most often used. A variety of different adhesives can be used to bond plastic prints, ranging from instant, epoxy, two-component to special adhesives for plastics. You should always refer to the information for the specific adhesive to see if it is suitable for the material. The adhesives are relatively easy to work with, however, especially with instant adhesives it is essential to take care of safety.

- Clean, dust and degrease the contact surfaces.
- Apply the adhesive to one of the contact surfaces (or according to the adhesive instructions).
- Using a skewer or other tool, spread the adhesive over the entire contact area.

- Bring the contact surfaces together and clamp until fully cured.

In addition to gluing, other bonding principles can be used, such as chemical bonding based on etching a part of the plastic (acetone, chloroform).

Surface smoothing

Another common practice used to process prints is to smooth their surface. The print is made up of individual layers and these are (more or less) not only visible but also embossed. As far as appearance is concerned, the surface can be further worked and smoothed by various methods or combinations thereof. In addition, after removing supports, brim or raft, uneven parts on the print may also appear - the surface often needs to be smoothed as well. Due to the techniques used in smoothing, detail is often lost, both in sanding and other smoothing methods. In addition, there is a risk of loss of material by grinding through the outer perimeters of the print. It is therefore advisable to print the model that we intend to sand in such a way that it has thicker walls.

Sanding is the simplest, but also quite laborious method of smoothing prints. We use sandpaper and mechanically sand the surface. The use of an electric sander is possible, but at high speeds there is a high risk that the material will melt as it heats up

instead of being sanded. It is therefore necessary to sand either by hand or very carefully with low sanding speeds. Sanding is very suitable for larger surfaces, while very small details are difficult to sand due to accessibility or, on the contrary, they will be sanded away.

Chemical vapours or baths (acetone, chloroform) can also be used for smoothing, but working with chemicals is not entirely safe in a school environment.

Sealing and priming

We use the **sealing** to fill rough holes or gaps in the material. In this case, material (putty) is added. Even so, it is necessary to work carefully to avoid disturbing any details of the print. In the case of fine details, puttying is practically unusable. We can apply acrylic putty but also silicone putty. It is advisable to combine the application of the putty with subsequent **sanding**. **Priming** is the application of a base colour, which not only serves as an intermediate layer for the eventual final finish, but also fills in minor irregularities - e.g. visibility of layers. Even for priming, we can combine the process with **sanding**. Also for priming it is necessary to choose paints that have good adhesion to the material and not to apply too large a layer.

Final surface finish

If we are concerned about the appearance of the print we often proceed to the final editing. We can take a practical approach to the final surface - e.g. applying a protective varnish - or a creative one - colouring the print to our liking with a range of colours.

Probably the most classic method of surface treatment is painting. You can paint the whole model with one colour but you can also paint it according to your wishes. If we don't have a multi-color printer (and even with it we are limited in the number of colors) we can achieve a full-color product. Before colouring it is advisable to apply a base colour (and possibly sand and seal) for a better colour hold. The paint can be applied with a brush, spray or airbrush.

By **varnishing** we mean applying a transparent varnish (matt or glossy) to the final surface. This varnish can be applied directly on the raw printed model (e.g. just to protect the surface) or as a layer on an already treated surface (sanded, painted, etc.). The varnish is again applied with a brush, spray or airbrush.

Polishing has already been outlined in the section on sanding, it is "just" a further refinement when sanding the surface using polishing pastes (preferably for plastics). This way we can achieve a fine, smooth and glossy surface even without painting and

varnishing. However, it is not possible to polish a rough print, it is always necessary to sand the surface first, up to a relatively high fineness (e.g. 3000).

