

Co-thinking and Creation for STEAM diversity-gap reduction

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3D Printing

CreaSTEAM CONSORTIUM

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Amendment History

Version	Revision	Date	Author	Modification
1	0	17/07/2021	JSR	Initial version

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1. INTROUCTION. HISTORY, WHAT IS IT? WHAT TYPES ARE THERE?

1.1. Brief History

3D printing leads to the time after the invention of the ink printer in 1976 It has never stopped experimenting with technology and since the appearance of the first 2D printers it was clear that the next step was to be able to print physical objects, beyond drawing them on paper.

The 80s is going to be a key period for the history of 3D printing. And it does so at a complicated time, because we are in an era where everyone still thinks about 3D (the boom in digital photography has not even arrived yet).

The birth of 3D printing

The first years of the 80s were marked by projects that failed or did not come to fruition. But they opened the door for others, with more refined ideas or more money, to follow in their wake.

It is from 1984 and, above all, during the second half of the 80s, when the events that lead to the birth of 3D printing as an industry are precipitated. During these years the first patents and companies are created. Sla, SLS and FDM 3D printing technologies are officially born.

SLA 3D Printing Source

The year 1984 is of vital importance for 3D printer's history. It was in that year that Chuck Hull invented stereolithography (SLA). This method of 3D printing is based on layered synthesis using a laser. A few years later, in 1986, Hull patented its invention and founded 3D Systems, the first company in the sector. 3D Systems will also be the first company to offer a commercial SLA 3D printer, specifically its SLA-1 model.

The beginning of the 3D printing SLS

A few years later the first alternative 3D printing system appeared. The year is 1987 and Carl Deckard, a researcher at the University of Texas, invents a system that synthesizes resin powder into a solid. This is how 3D SLS printing is born. Like Hull's invention, the machine devised by Deckard works with a laser, but synthesizes dust instead of liquid resin. The first machine Deckard designed with this system was called Betsy.

However, although it's true that this method of printing emerged quite some time ago, the first commercial SLS 3D printer did not appear until 2006. Therefore, his path in the history of 3D printers had only just begun.

FDM 3D printing, the third to arrive

FDM 3D printers are the best known today and represent a large percentage of the market. Many might believe that the first 3D printers in history had this system, but in reality, it is the third in discord to appear.

FDM technology is based on molten filament deposition. The filament is heated so that it can be extruded through a nozzle and deposited on a hot platform or bed.

1.2. Printer Types

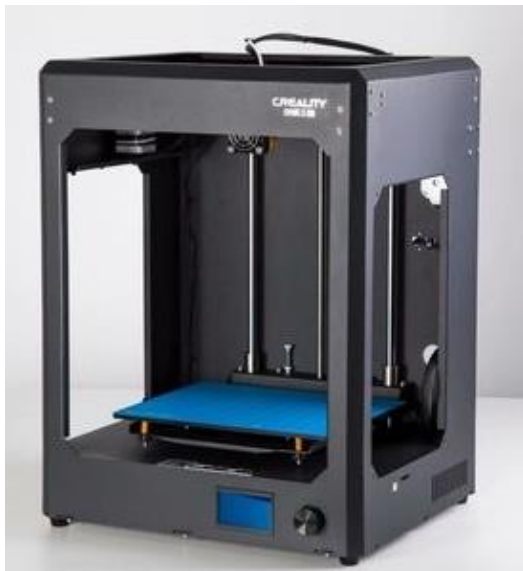
There are mainly 3 types:

FDM (Fused Deposite Modeling)

Manufactured from filament melting. It allows the creation of 3D elements from different materials (plastic metals, wood...). It is resistant to shocks, but not to high temperatures. It's the cheapest technology.

It uses an extruder and allows the material to be melted and be deposited in layers on the X and Y axes. The most common materials used are PLA, ABS, PETG and TPU; being the easiest to work of them all the PLA.

We can find them opened or closed with walls.



SLA y SLS (Synthetized)

Technology also called Stereography. The material used for the manufacture of 3d objects is resin.

Parts created using this technology have a higher definition then FDM.

It uses an ultraviolet light laser to guide the resin extruder that corresponds to the 3d object.



DUST

Technology that uses ceramic dust and a liquid binder for the manufacture of 3D objects. It is not very resistant.

The process is developed by sweeping the "Cartridge" that carries the liquid binder on the powder to fix the solid walls of the design.



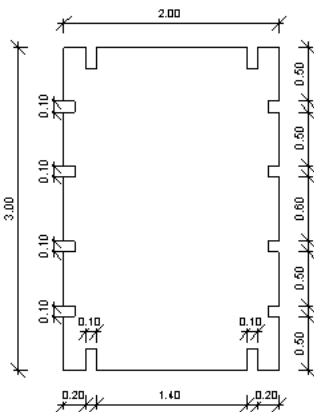
2. CASE STUDY

During this class, we will start the process of design and printing of a piece starting from a real practical case made by the students of the subject of Computer Tools of the University La Salle Ramón Llull.

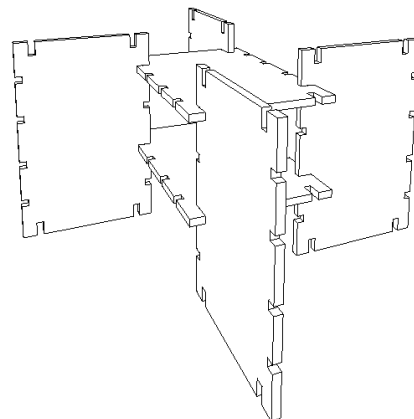
The exercise is within the framework of the Edugame4city project.



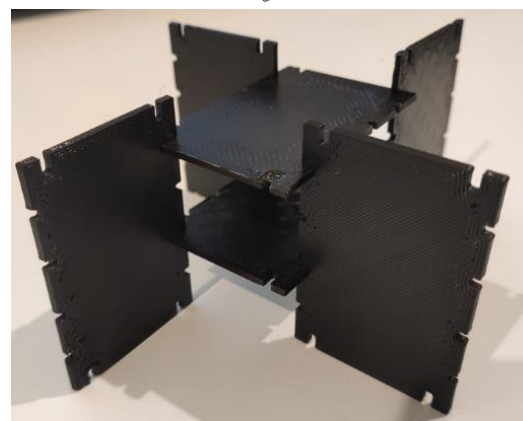
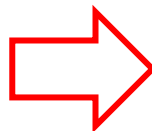
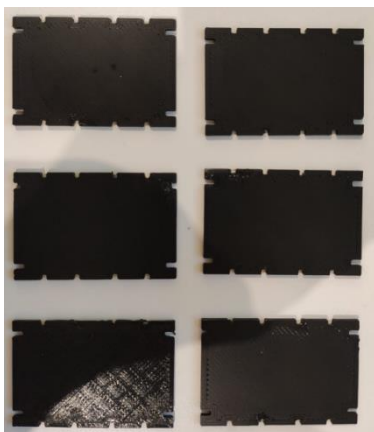
Inspired by the card game created by the architects Charles & Ray Eames in 1952, where from a series of cards you can build different shapes and spaces, students are proposed to design in 3D their own cards, of large dimensions, to mount a fictitious pavilion in a real urban space.



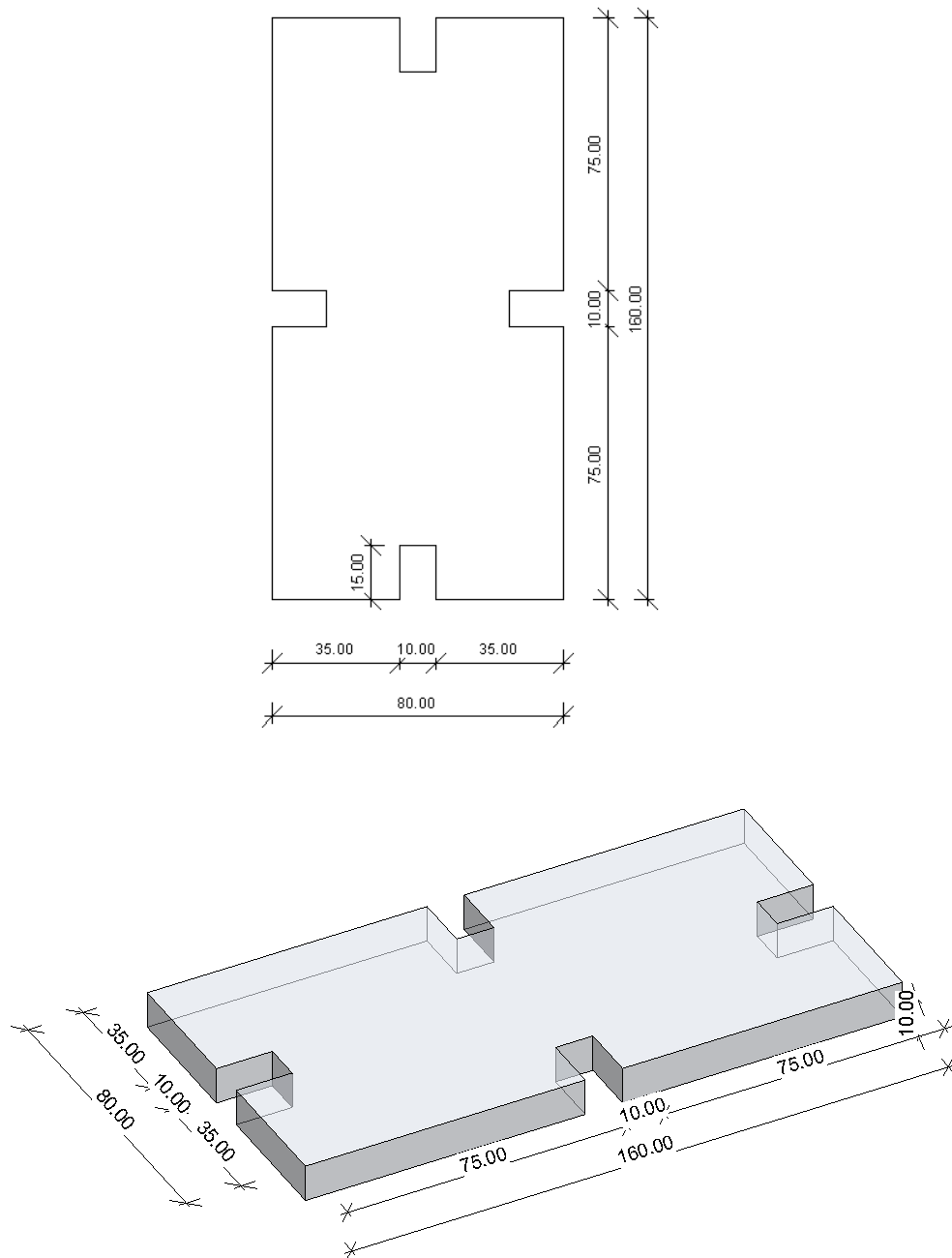
From 3D design tools, the students design a series of pieces builds a virtual model and a physical model a 3D printer...



then with



We will design and print a simple piece from a 3D modeling tool, which we will then print and replicate as many times as we need to create a physical model.



3. TOOLS NEEDED TO CREATE AND PRINT IN 3D. INTERFACE AND INITIAL CONFIGURATION

To be able to create and print our own pieces we will need 3 different tools:

- 3D Modeler
- 3D Laminator
- 3D Printer

Note: *How to obtain the tools and initial configuration is explained in the Attached documentation.*

3.1. 3D Modeler. TINKERCAD

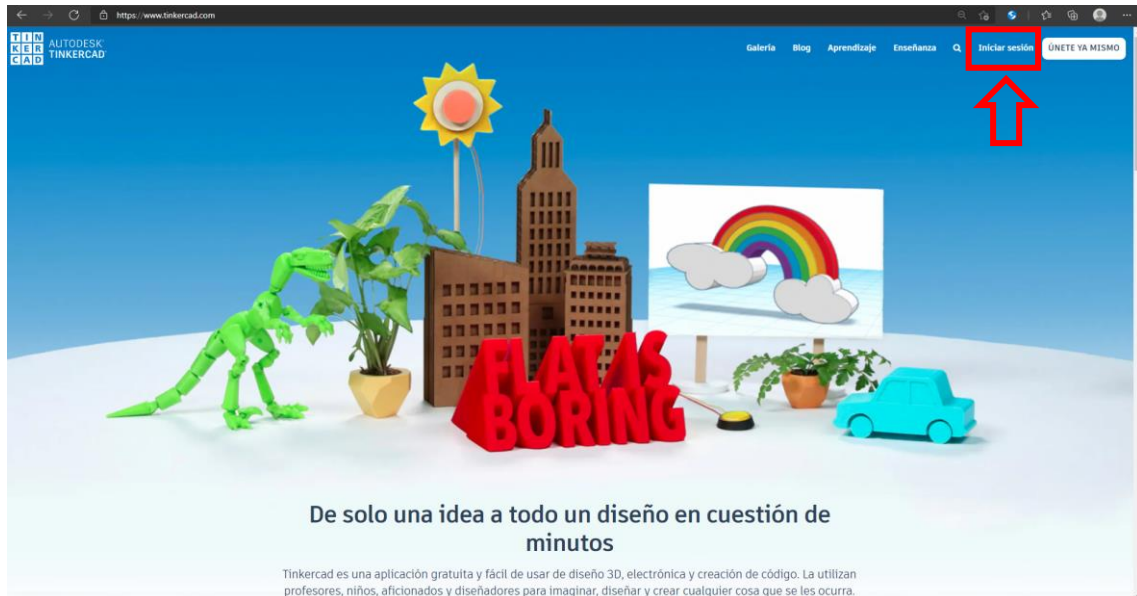
There are many programs that allow us to create custom three-dimensional designs to be able to print them later: Autocad, Revit, Fusion 360, Rhinoceros, Sketchup, Tinkercad, etc. Each software is focused on a different profile (engineers, architects, students, etc.) and has different learning curves.

In this case **Tinkercad** will be used as modeling software, for the following reasons:

- It is focused on education, for beginner users.
- The learning curve is small.
- It's online.
- It is free.

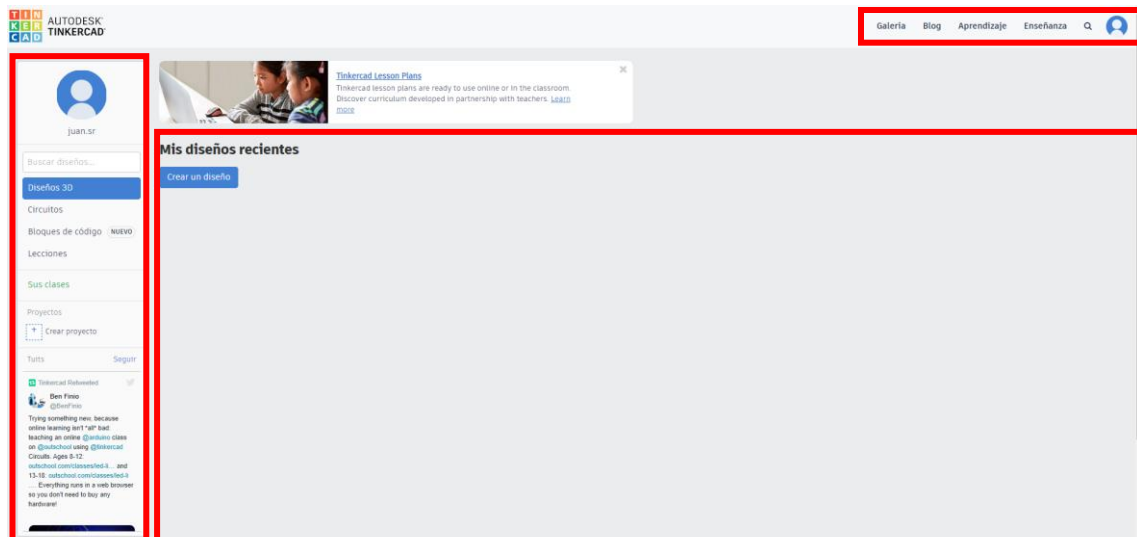
Initial interface and project creation.

From a created Autodesk account, we'll <https://www.tinkercad.com/> and sign in.

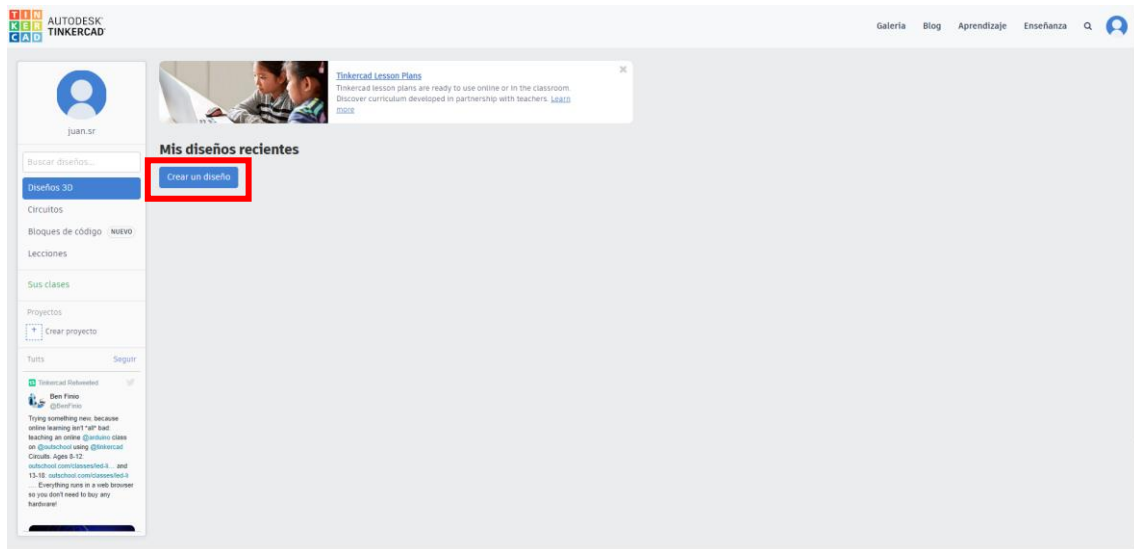


The interface that appears is divided into three parts:

- 1- Gallery panel of other users' projects, learning lessons, training and account control.
- 2- Personal panel of created projects, designs, classes created and to which it belongs.
- 3- Panel where the created designs are displayed.



To create a design from the beginning, click on the button "Create a design"



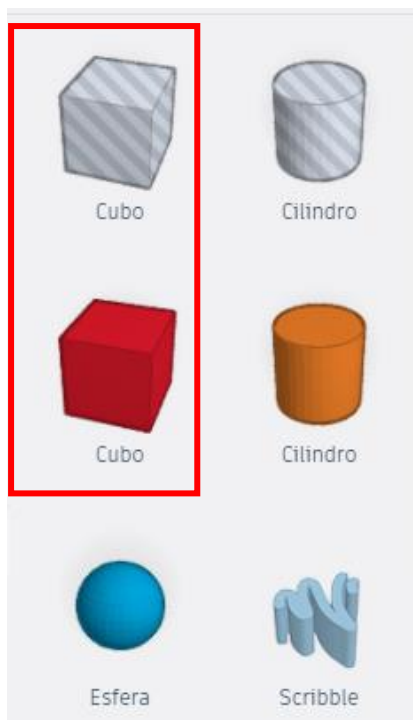
Model Interface



- 1- Browser interface.
- 2- Menu general tools and operations booleanas: Undo and redo, delete, join and separate elements, import of other projects and export, Etc.
- 3- Work menu: models to use in the project, creation of additional drawings and measurement tool.

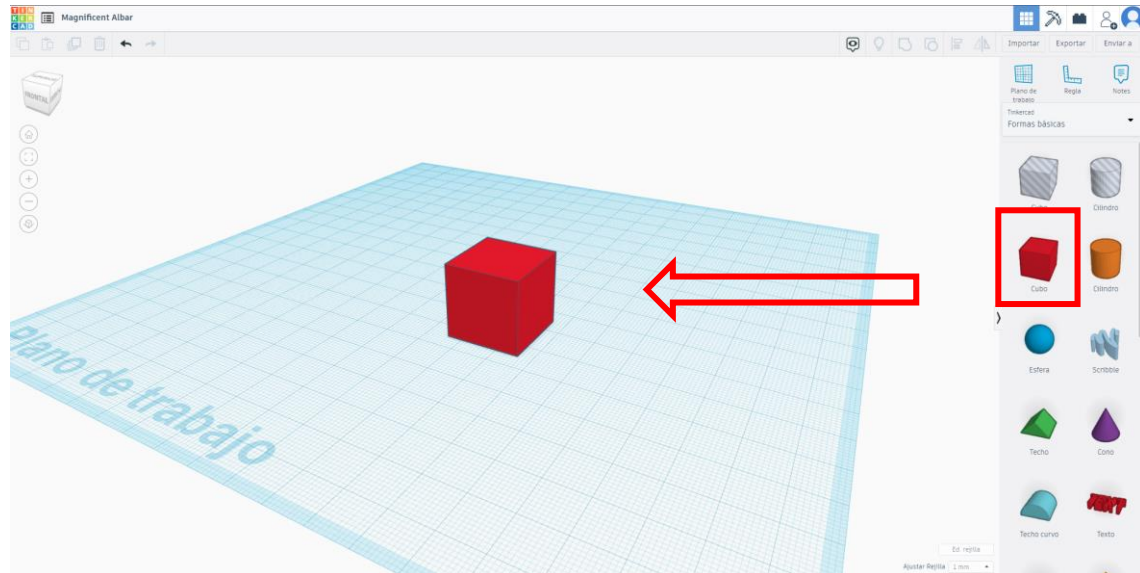
For the design of the part that we are going to create we will use only two shapes: The solid cube and the empty cube.

We will use two basic ways to model our part through boolean operations.

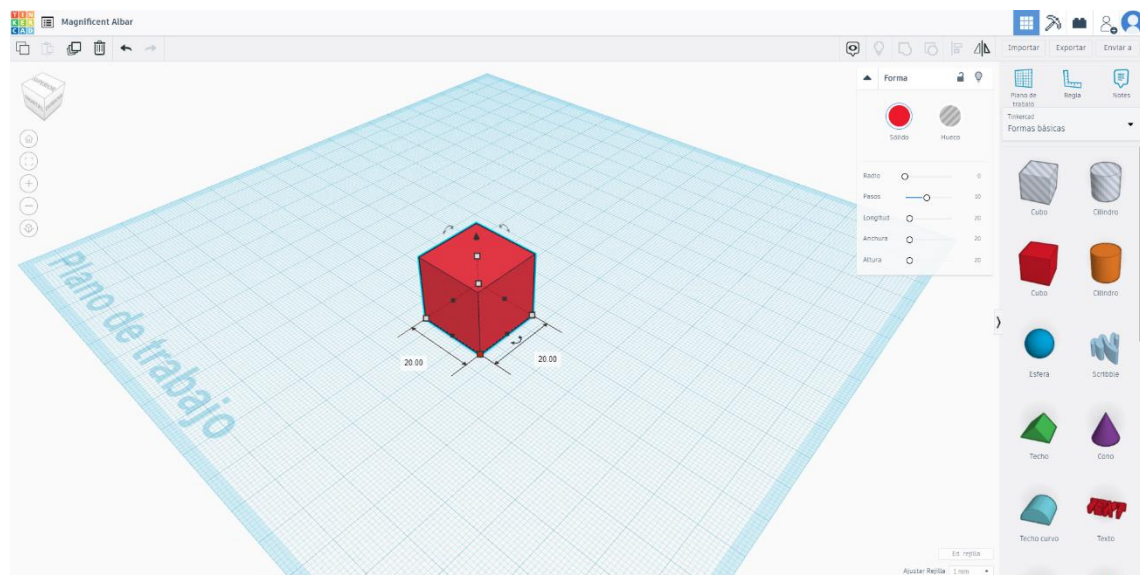


Part Design

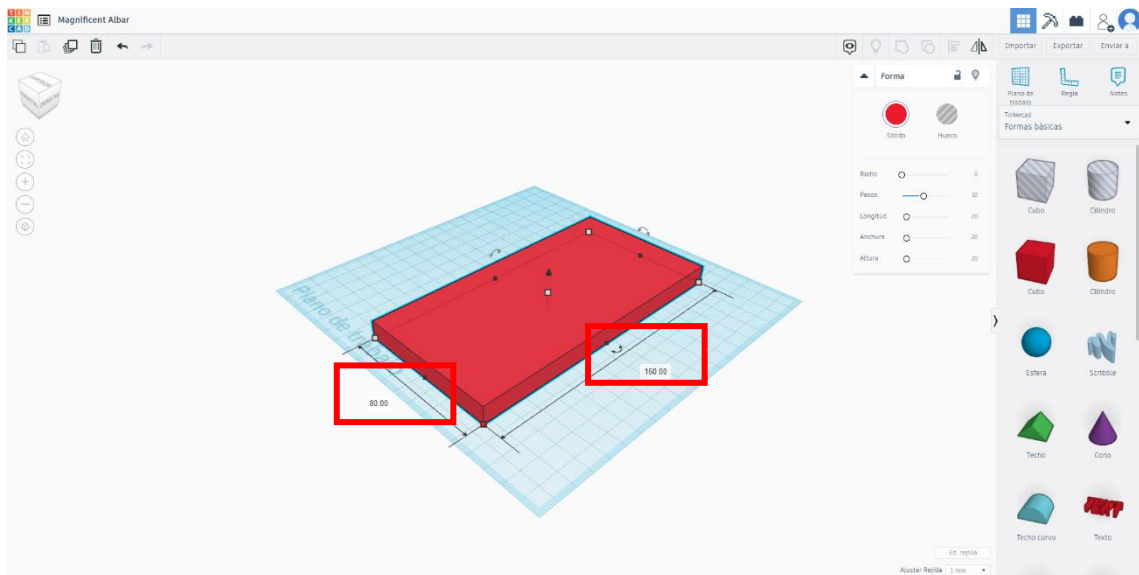
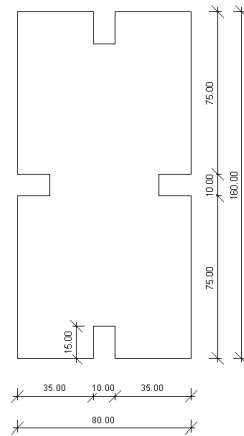
- 1- Click with the left mouse button and hold it down on the red cube icon and drag it on our work plane.



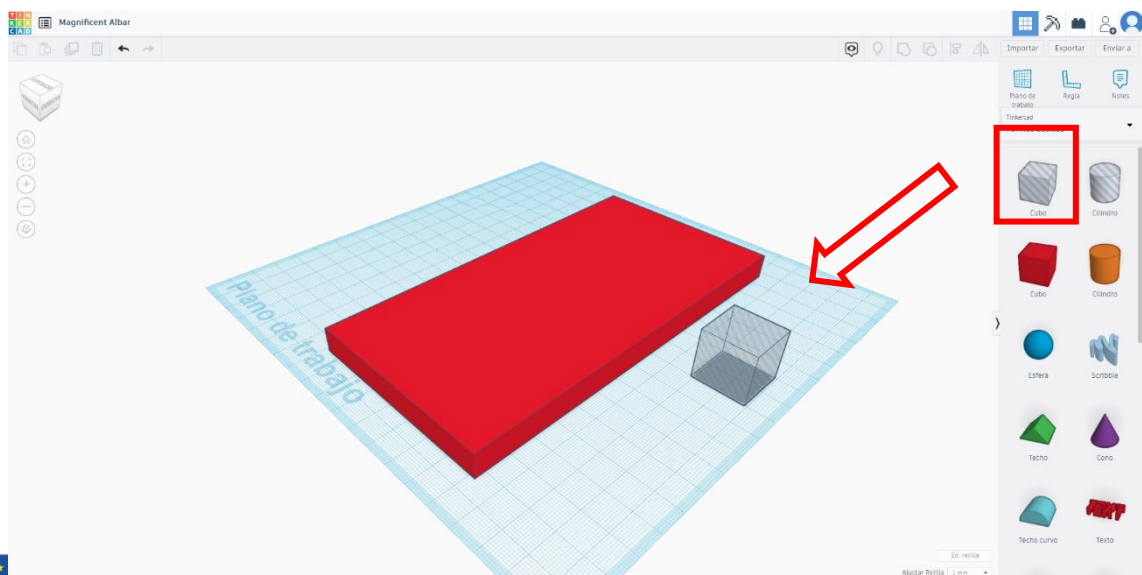
Click on the inserted cube, we will see that a series of gripping points are activated. On each point that we touch it will allow us to modify the dimensions that are activated.



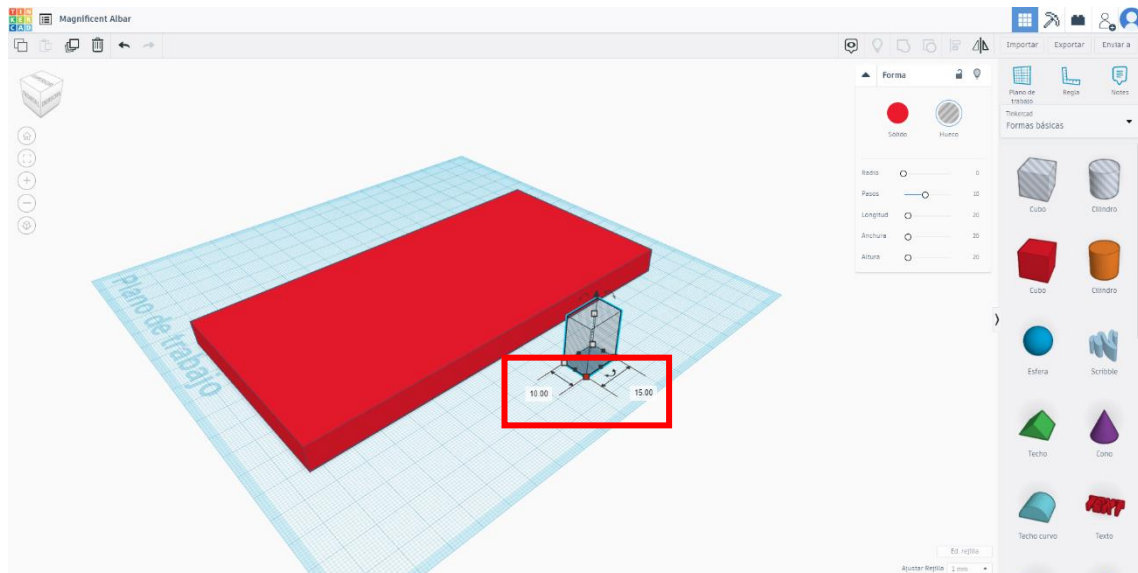
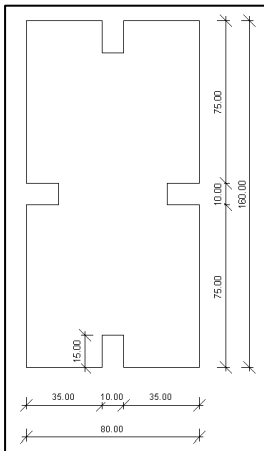
Now we will modify, clicking on the vertices and then on the activated dimensions, the shape of the original cube to obtain the general measurements of our piece. 80x160x10mm



The next step will be to generate the part slots. For this we will use the empty cube shape.



What we will do now is give the empty cube the dimensions of the groove of the piece. 100x150mm.

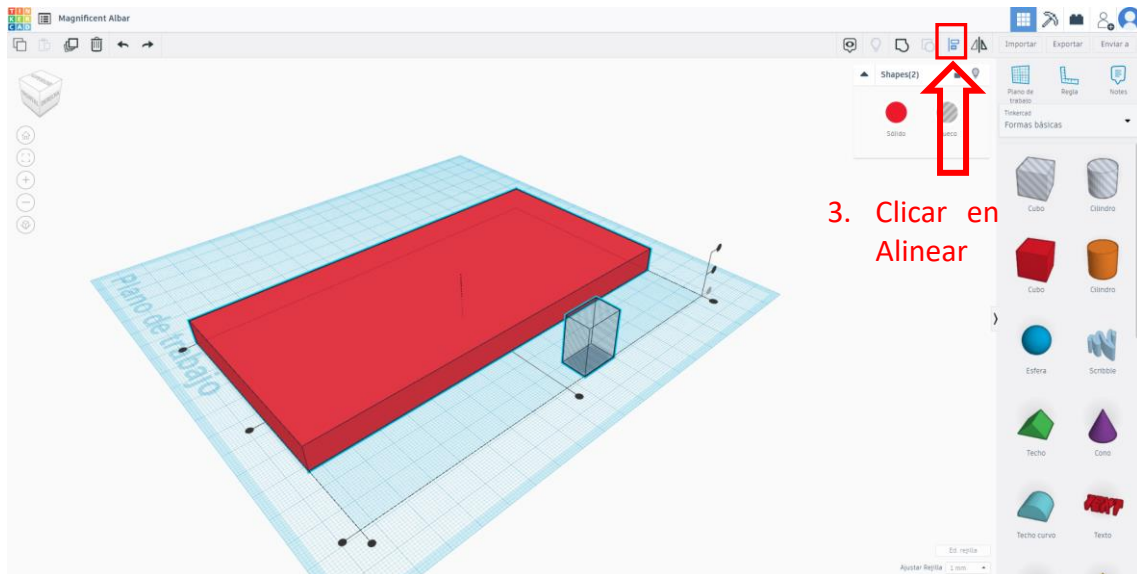


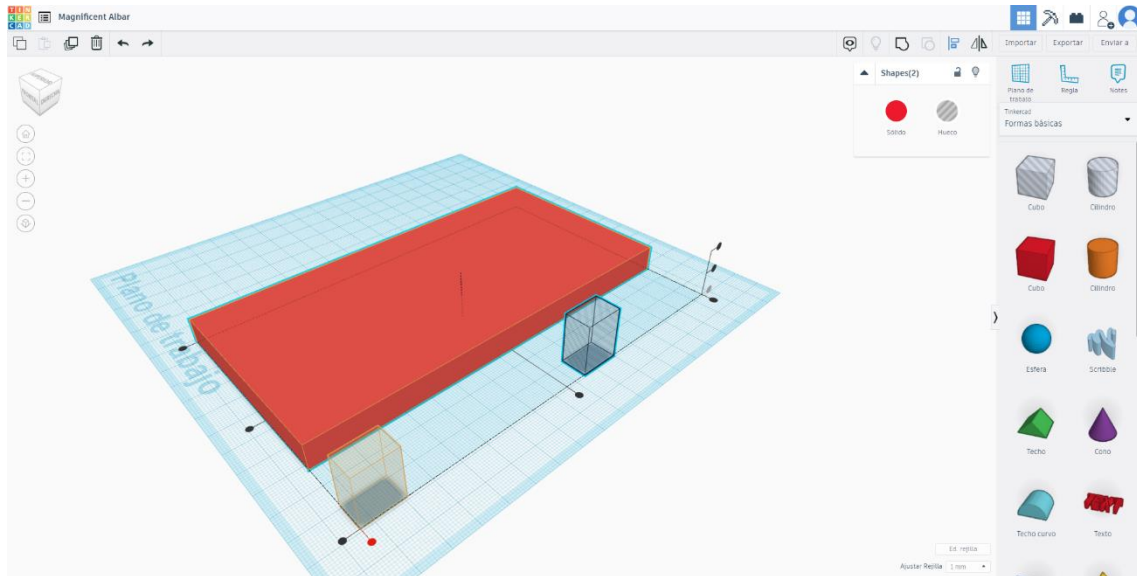
The next step is to align the empty piece with the first of the faces of the solid cube. The part that has been designed has a groove at the midpoint of each side. To do this, what we must do is align the empty shape with the solid part as follows:

- 1- Click on the solid piece and hold down the Shift key. (Capital Shift.).
- 2- Without releasing the Shift key, click on the empty shape. In this way the two selected pieces are left.

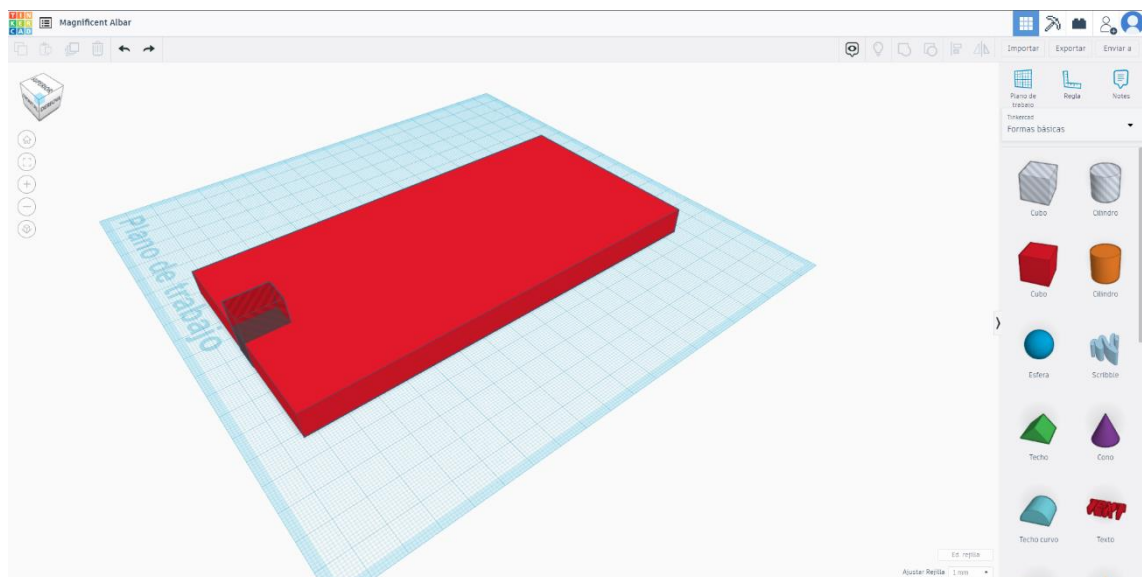


1. Click on the "align" icon. We will see that some references are activated and when you hover over them, the resulting movement is previewed. To align one piece on top of another, we have to click on top of the "target" piece to which we are going to align empty shape.

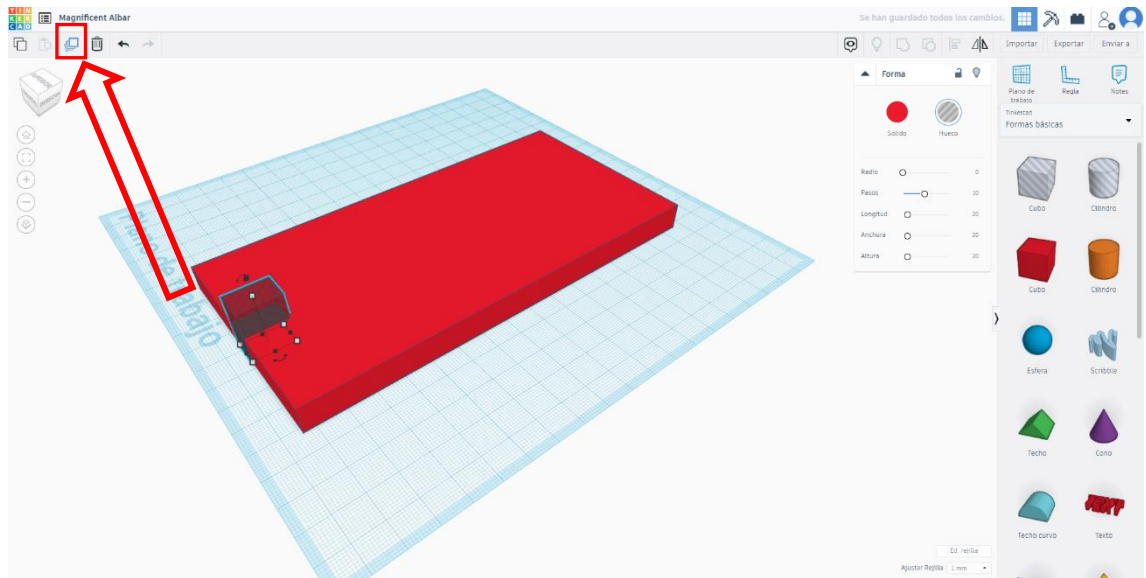




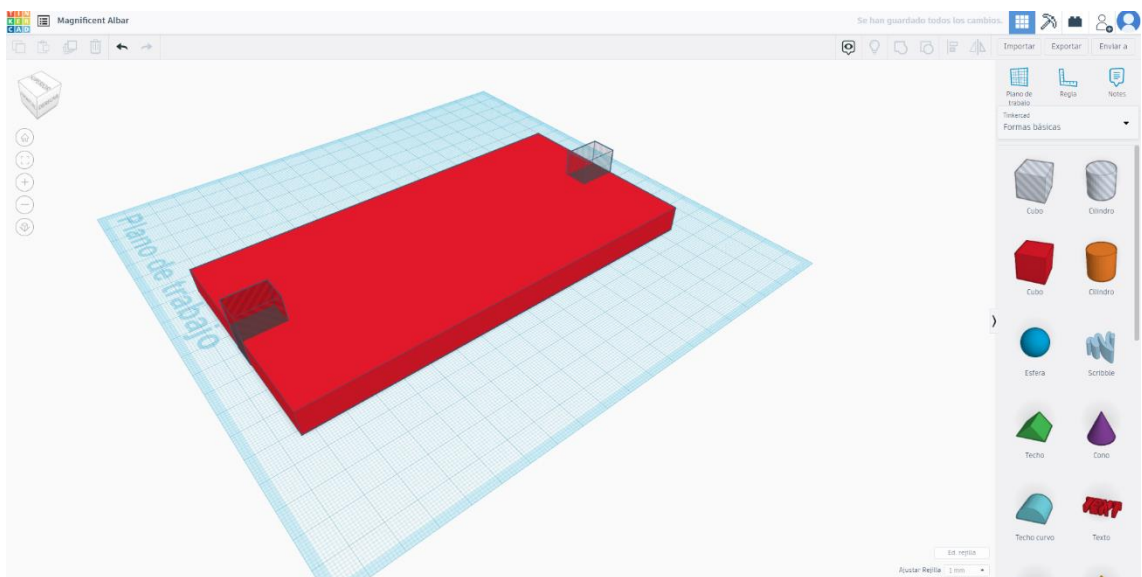
- 1- We will place the piece so that it is at the midpoint of the first face. The result must be this.



To place another empty shape on the opposite side what we will do is first duplicate the empty shape, first selecting the shape and then clicking on "duplicate".

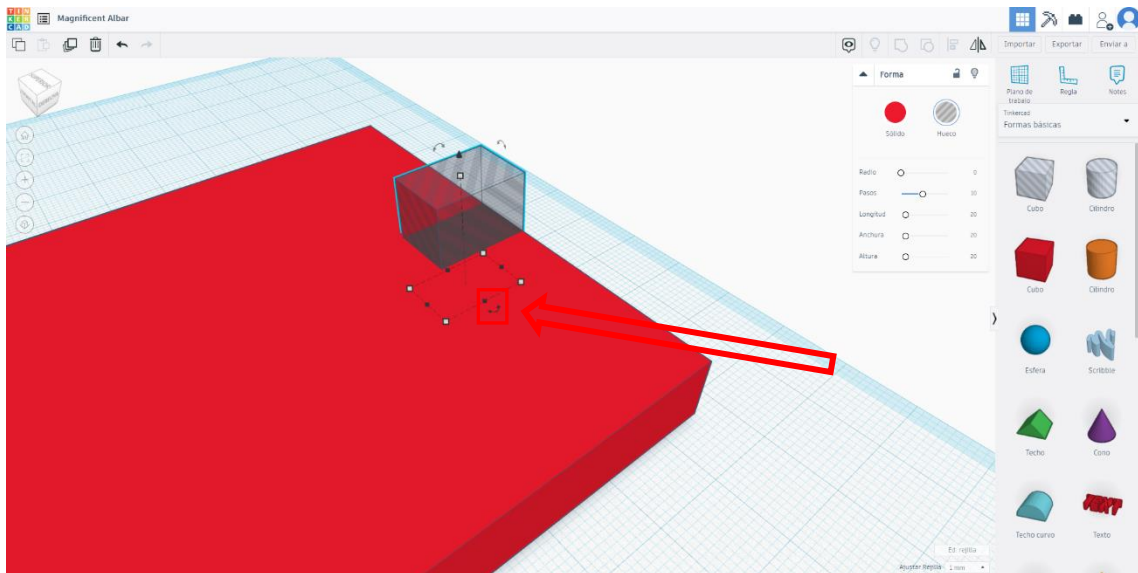
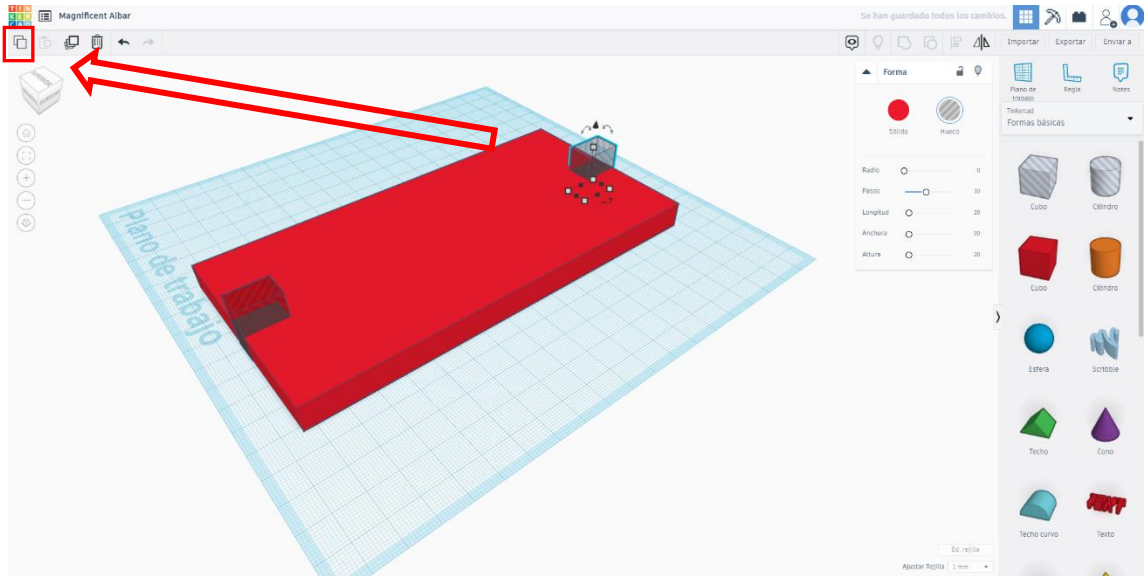


The next step is to align to the opposite side. As we did in the previous step.



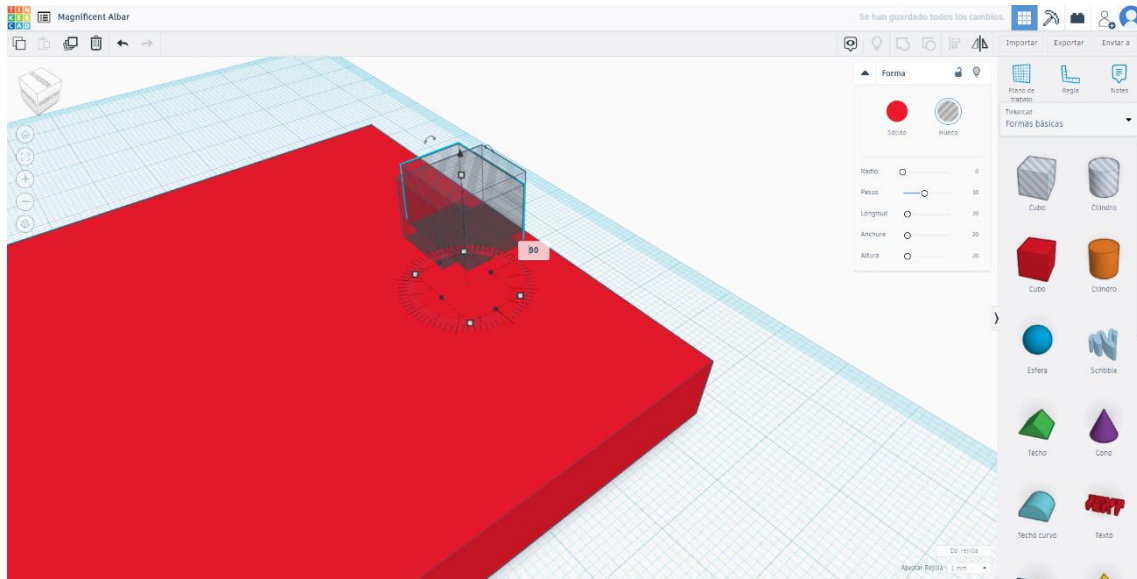
To make the gaps of the side faces we will repeat the duplicate of one of the two shapes that we already have, and we will rotate it 90 degrees with the reference that is activated when selecting the piece.

3D Print



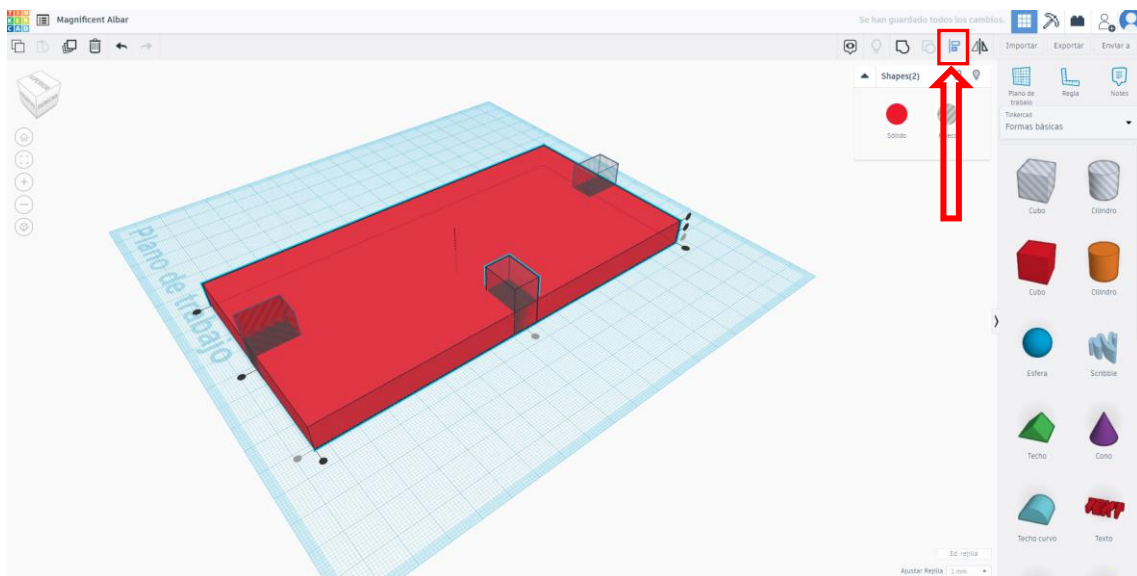
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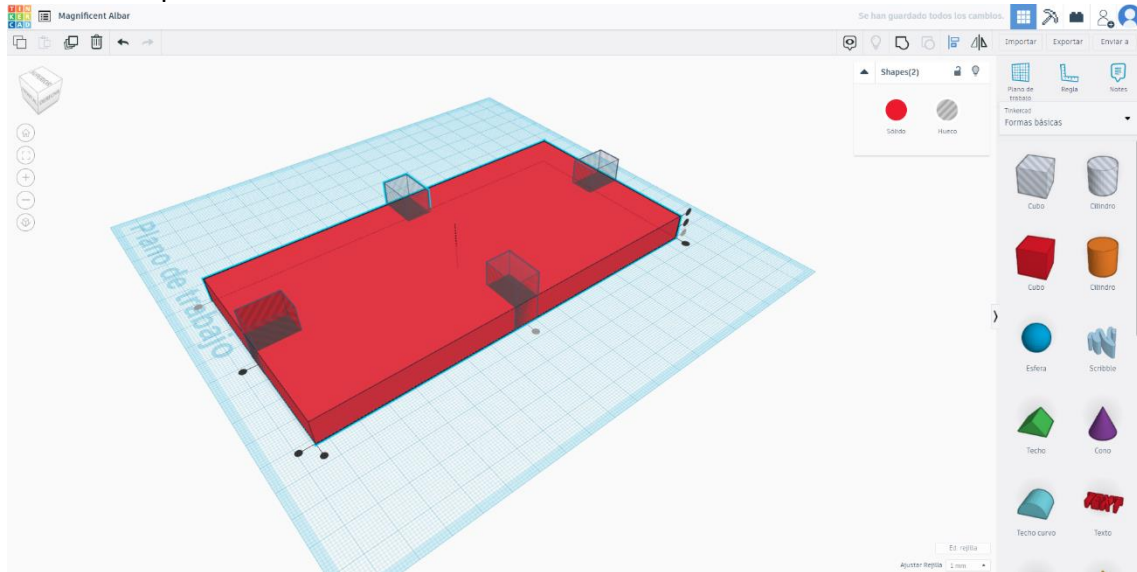
Now we'll align the rotated piece of 90 degrees to one of the midpoints of the remaining side faces.

- 1- Click on the solid piece and hold down the Shift key. (Capital Shift.).
- 2- Without releasing the Shift key, click on the empty shape. In this way the two selected pieces are left.
- 3- Click on the "Align" icon. We will see that some references are activated and when you hover over them, the resulting movement is previewed. To align one piece on top of another, we have to click on top of the "target" piece to which we are going to align empty shape.



We will repeat the duplicate of this last piece and align it to the opposite side of the solid piece. In this way we have already placed the pieces that will generate the vacuum

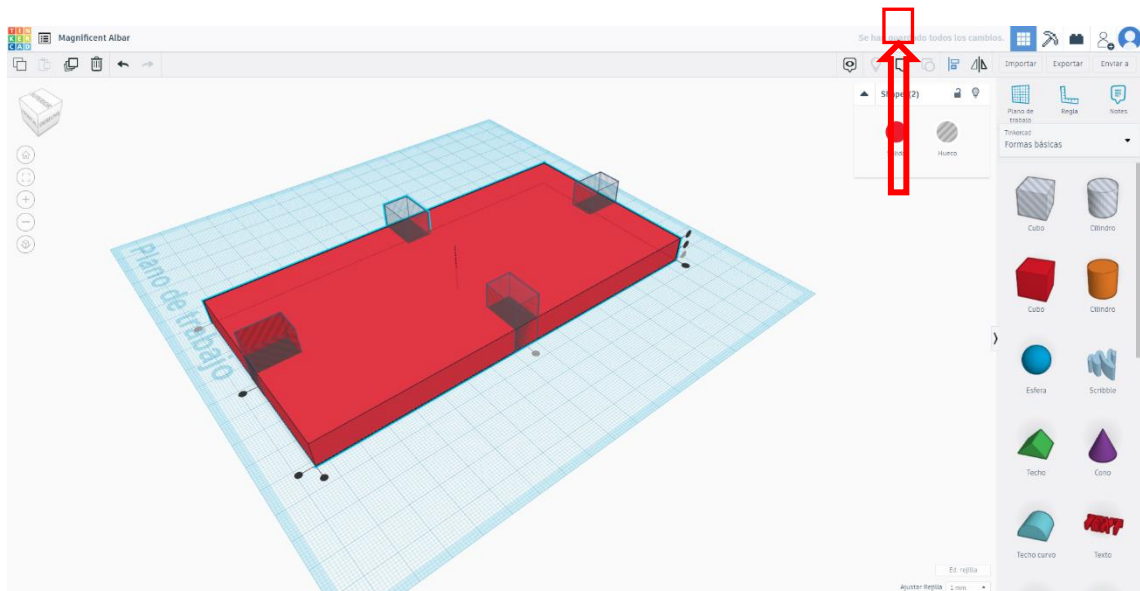
of the solid piece.



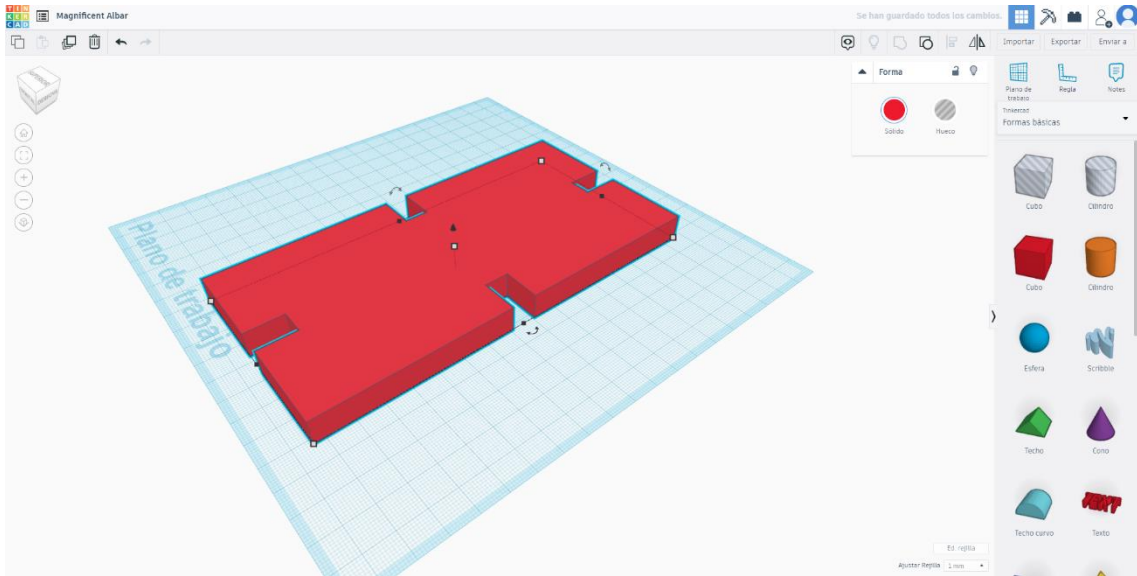
To finish with the design of the piece we have to perform one last step. We will join the solid piece with the empty ones. In this way we will have generated the slots.

1. Click on the solid piece and hold down the Shift key. (Capital Shift.)
2. Without releasing the Shift key, click on each empty shape. In this way all the selected pieces are left.

1- Click on the "group" icon.



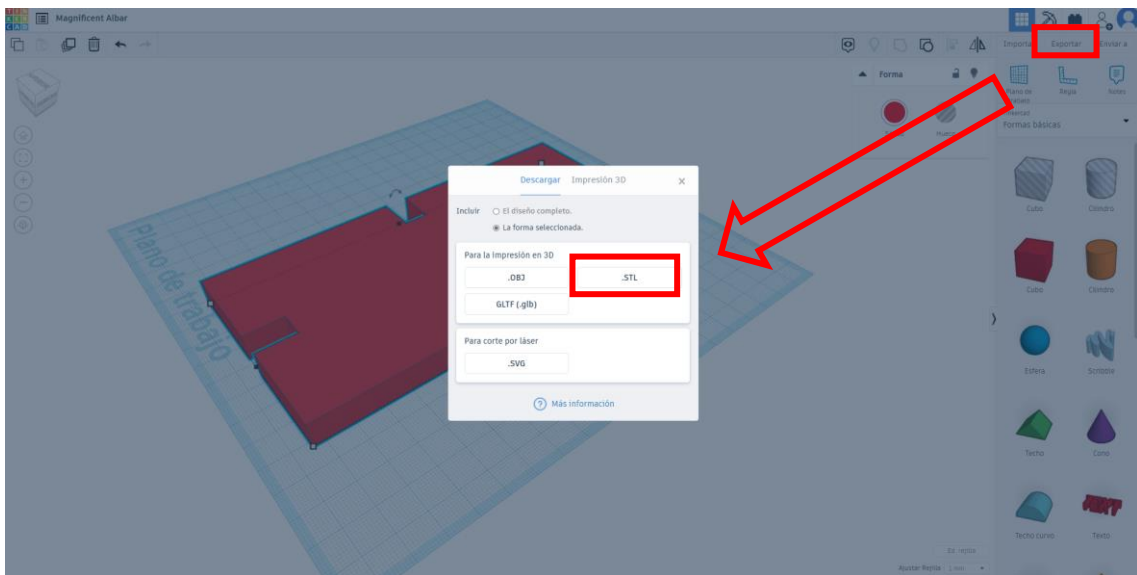
We have now created our piece.



Export the part for printing

Once the part is created. The next step is to export our design.

To do this we will go directly to the "export" icon and choose the ".stl" export format. Clicking will download a file to our computer. This is the file that we will use in our laminator to print our piece.



3.2. Laminator. CURA

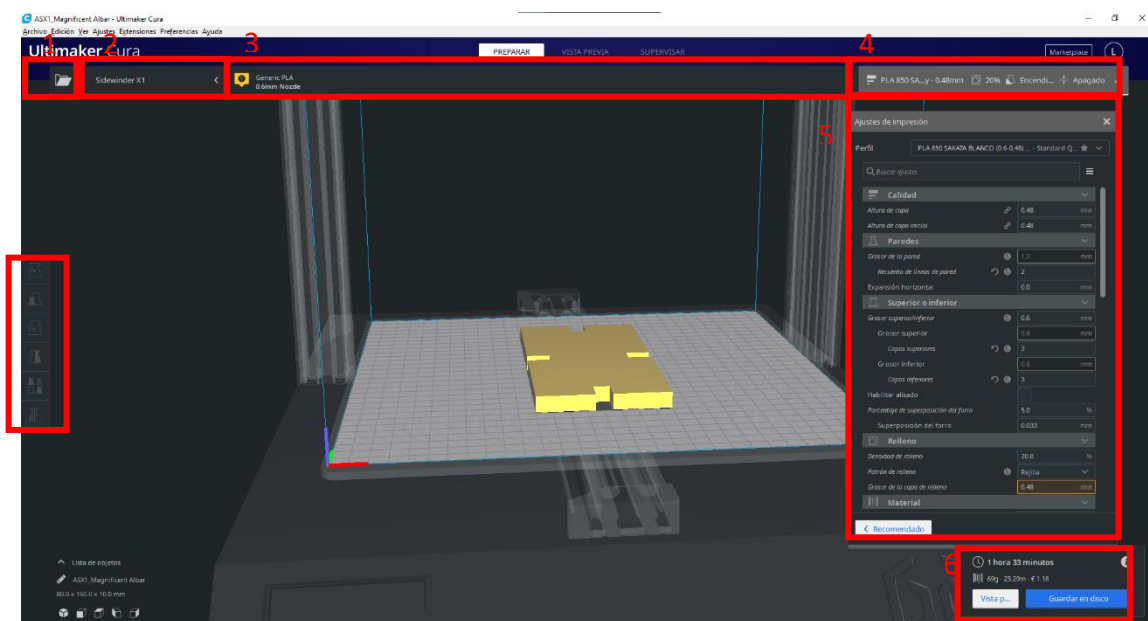
The laminator program will allow us, from the project created with the modeler, to prepare a file that can be printed depending on the type of printer we have, the material with which we are going to print and the definition we want.

The most used laminators are: Slic3r, PrusaSlicer, Simplify3d, Cura Slicer, MakerBot Print, etc.

In this case **Cura Slicer**, version 4.10 (the most current at the time of creation of this document) will be used for the following reasons:

- Simple initial setup.
- Friendly user interface.
- Good definition of laminate.
- It is free.

Interface

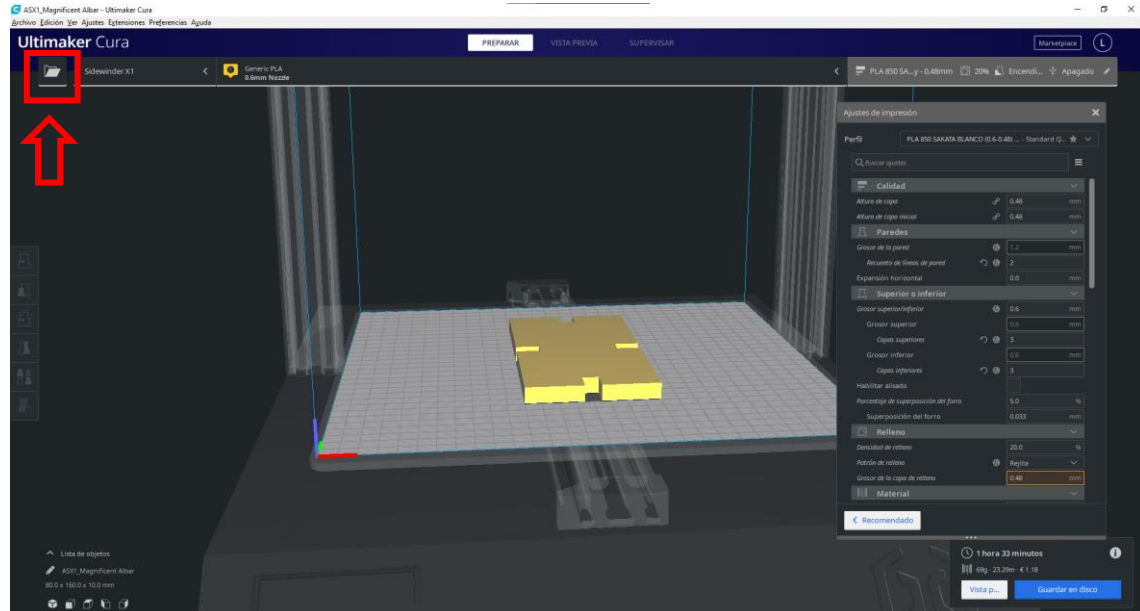


1. Open .stl file
2. Choice of printer
3. Menu of configuration of print presets of start depending on the width of the nozzle and the material to be printed.
4. Show/hide print settings. Summary of the configuration of the print settings profile used.
5. Configuration panel of custom print settings.
6. Laminate of the figure and stored.

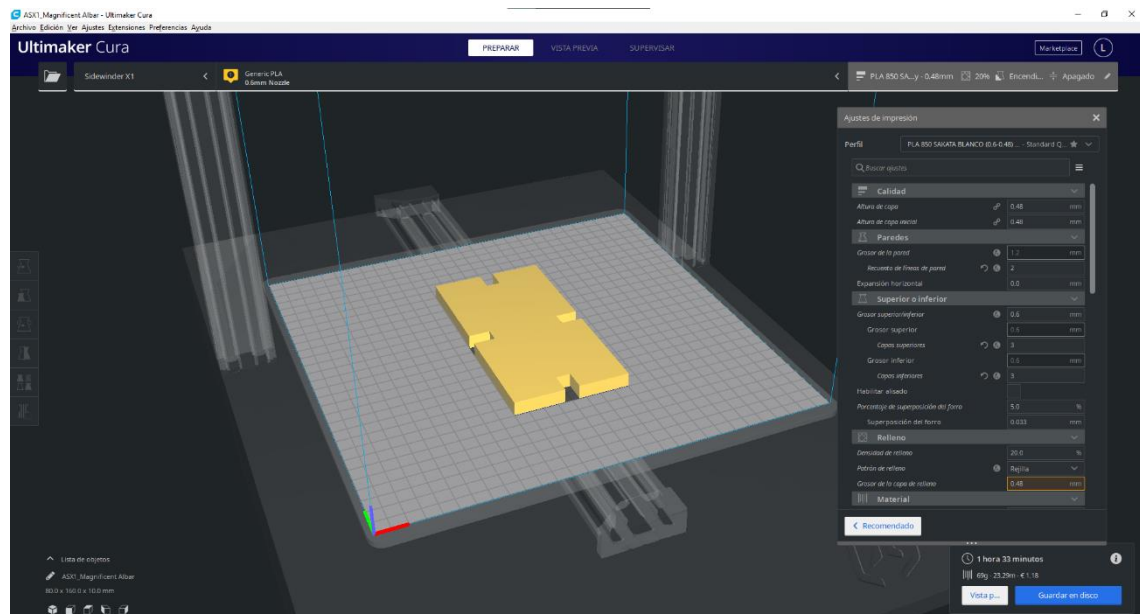
Import created .stl file.

We open the CURA laminator program and import the design created from the location where we have it.

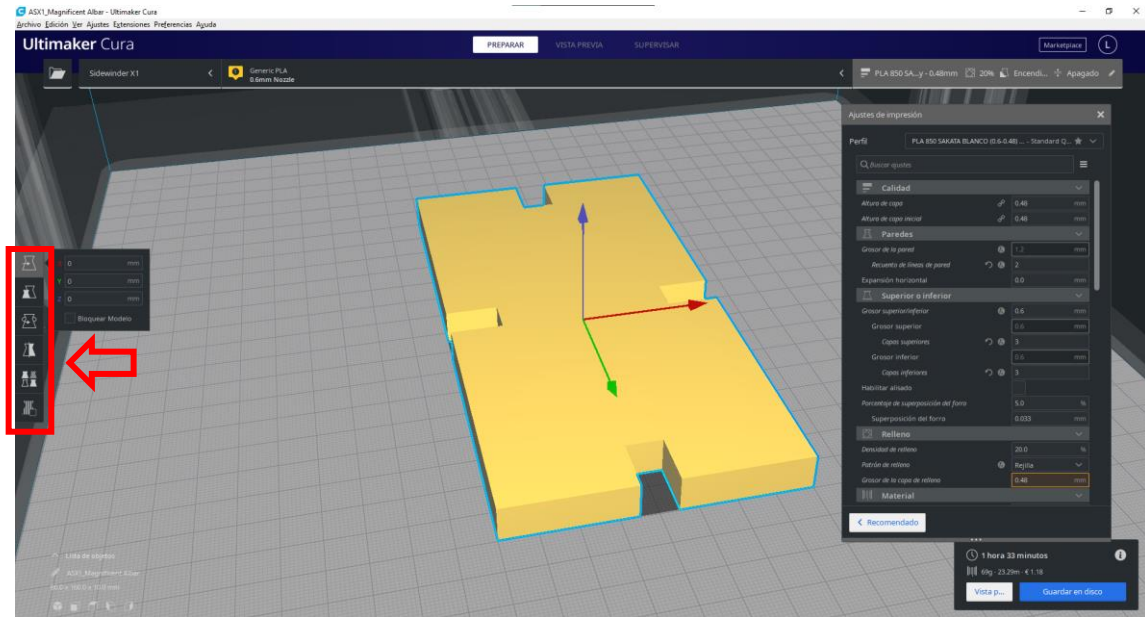
File → Open File(s)



We already have our design inside the laminator.



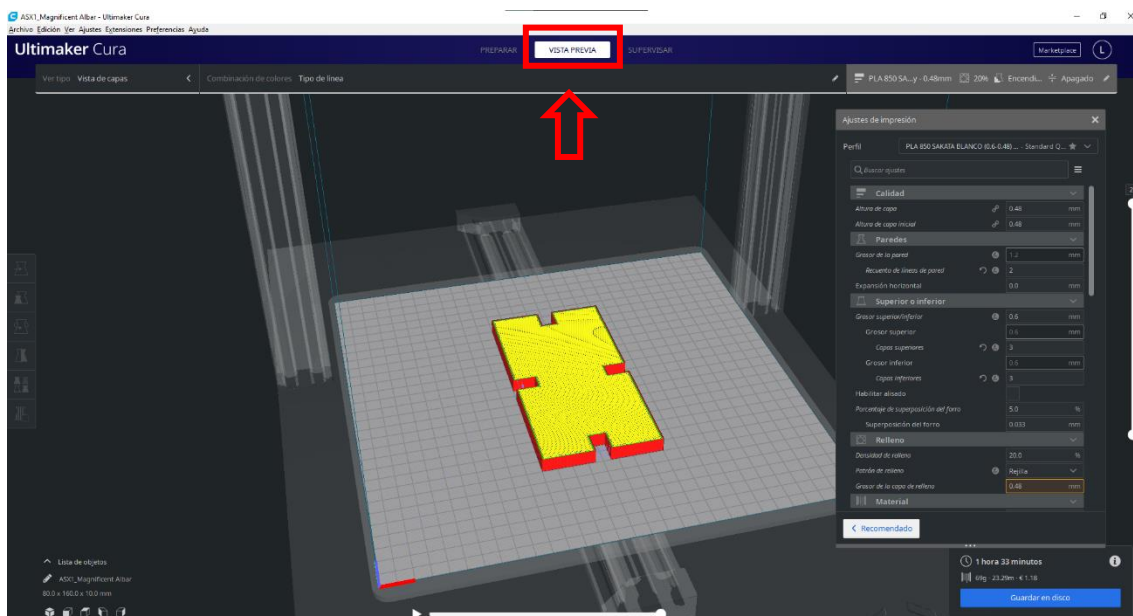
When we touch the left click piece with the mouse on it, the left side menu is activated that allows us to move, rotate, scale, duplicate, the piece, etc.



Main parts of the piece to be printed.

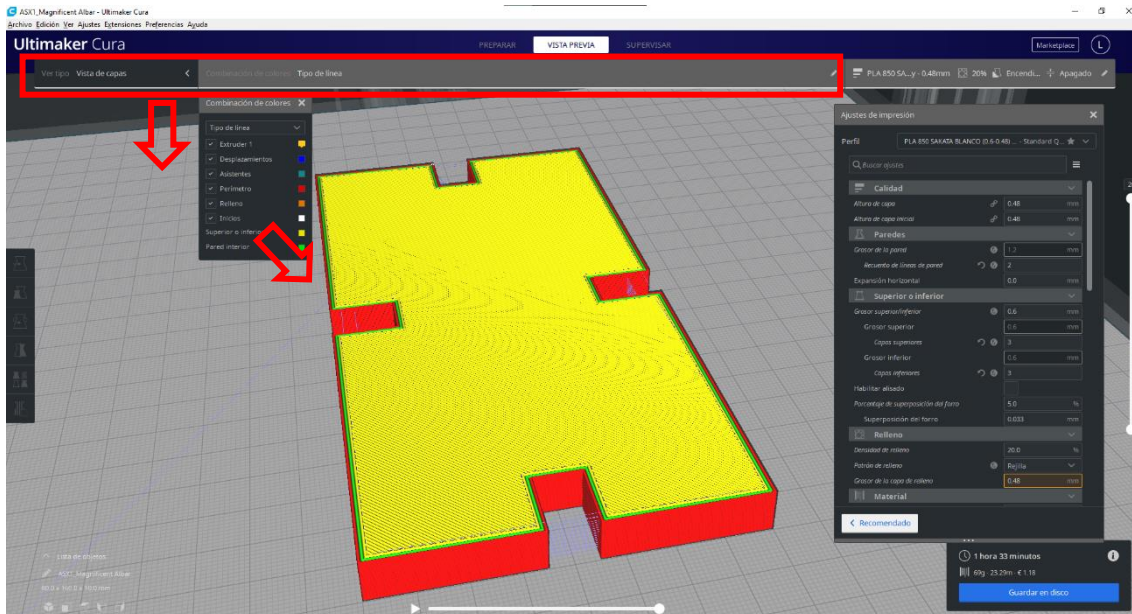
To make the general adjustment of the part parameters it is first important to see which parts are printed:

We will click on preview, to see how the piece is looking for now and how is going to be printed.

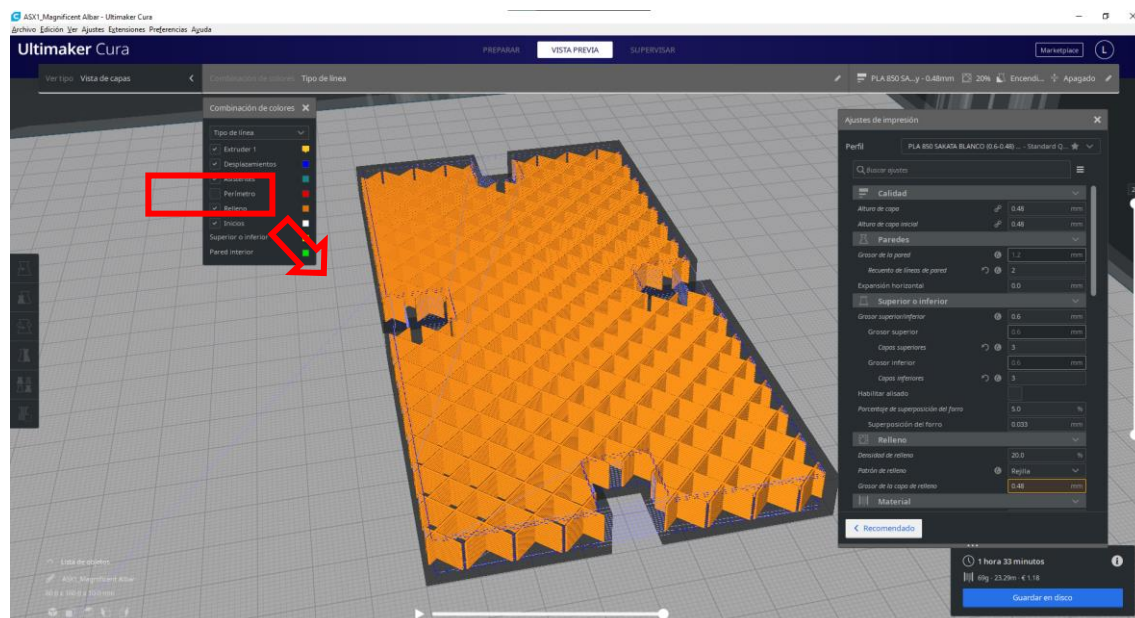


The "Preview" style shows us the different parts that are printed of the piece. It separates it by colors. This makes it easier for us to understand what parameters we need to touch next to set up our print.

We see that the housing of the piece has been separated into 3 parts differentiated by colors: **Outer perimeter (red)**, **inner perimeter (green)** and **upper padding (yellow)**



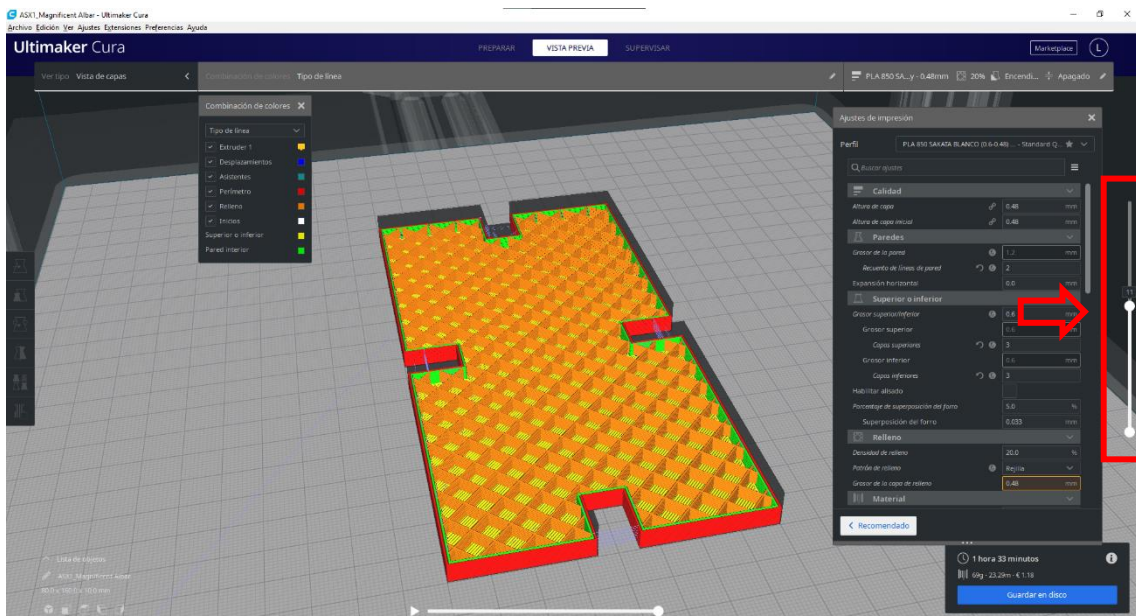
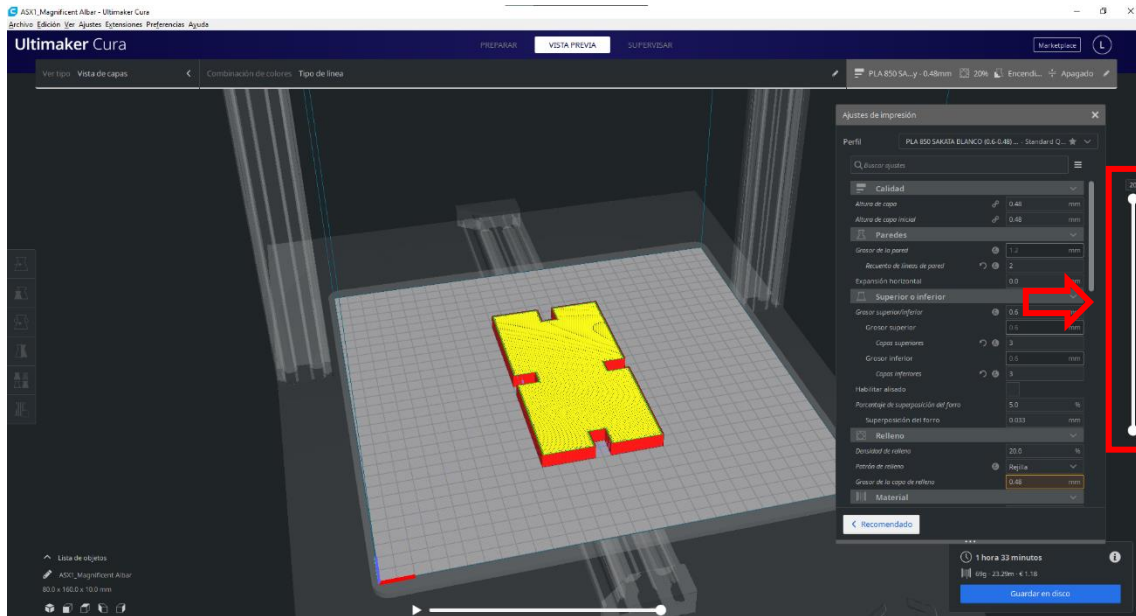
When we deactivate the layer "perimeters" we see that the piece has a orange fill inside the piece.



We will see that a slider is also activated on the right side of the screen.

The value at the top of the slider tells us the total number of layers that the laminator creates with the current print settings.

The Slider shows the piece at the height of the layer we want to see. We'll lower the slider value to see how the print is created.



Print settings.

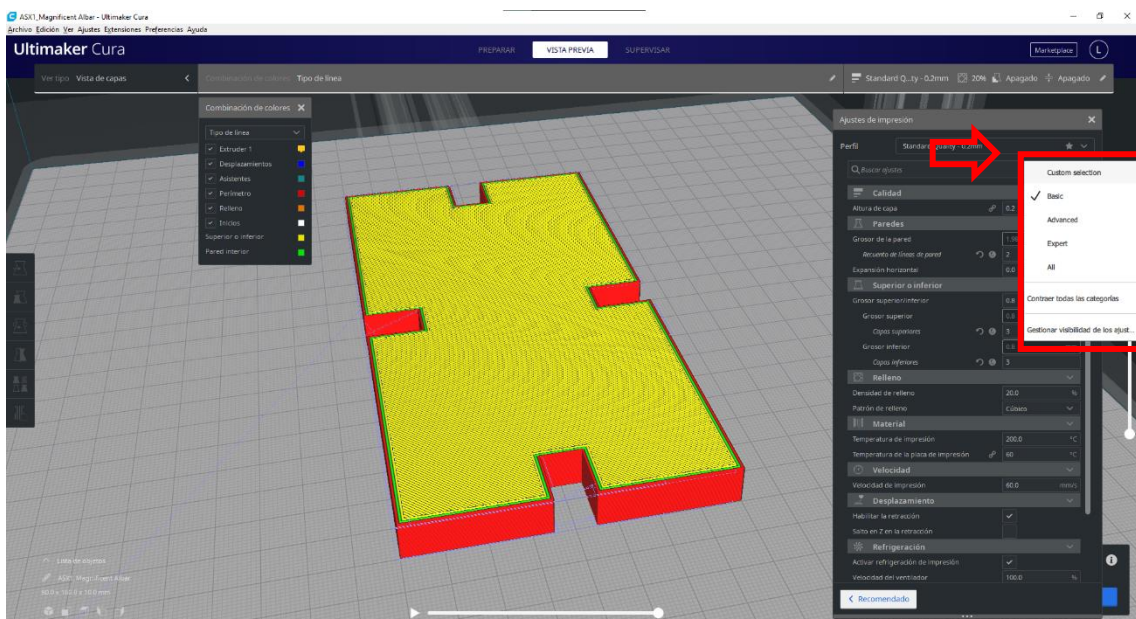
Now we have seen the main parts that are printed of a piece and that we must adjust in our printing:

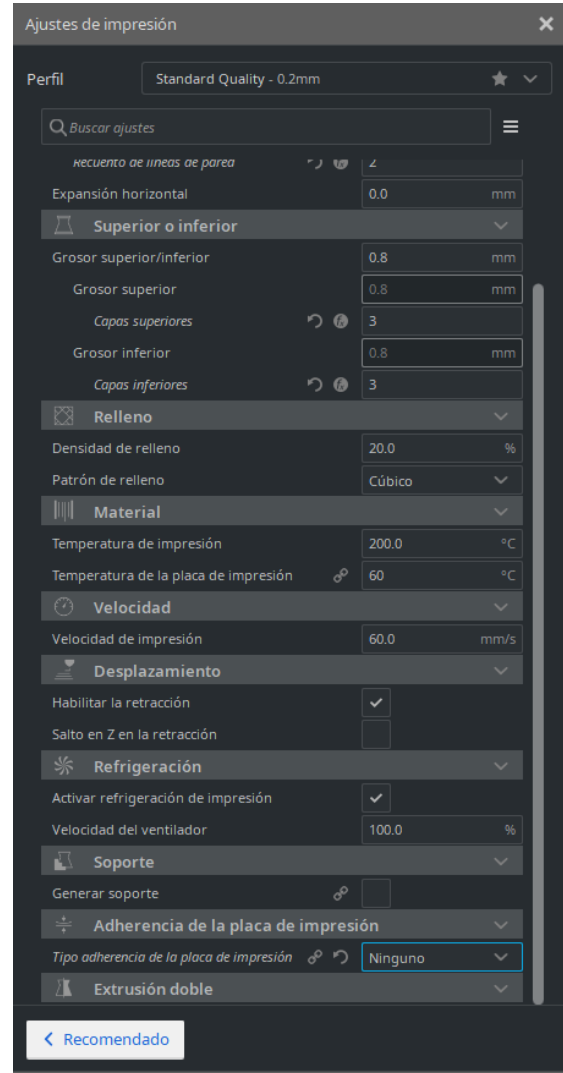
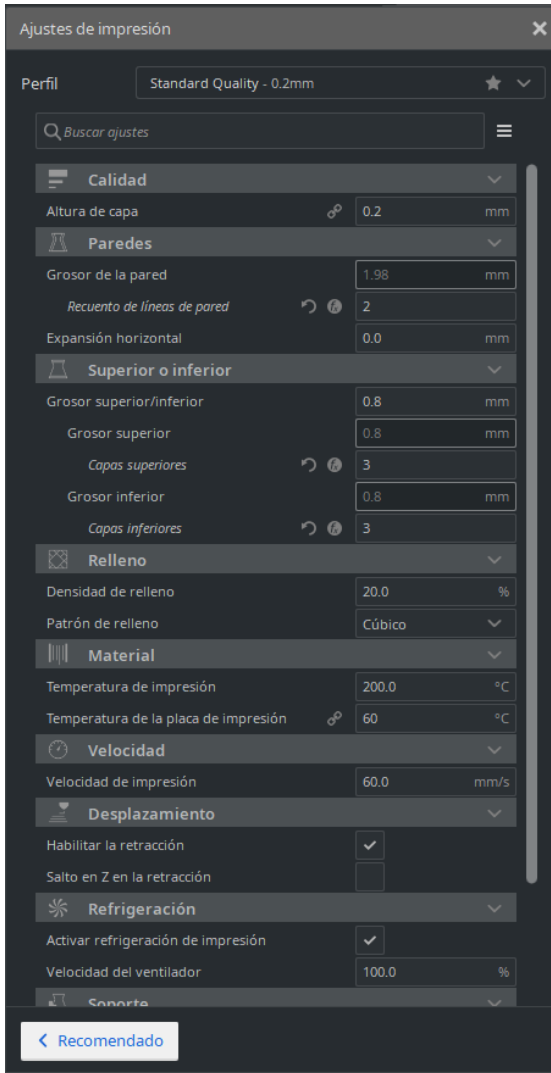
- Interior and exterior perimeters
- Upper and lower layers
- Padding

The other main parameters that we will adjust to make the printing optimal are:

- The printing temperature.
- Print speed

We'll focus on the right-side menu of "print settings". To the right of the settings finder, we will click on the icon of the 3 horizontal lines and choose the Basic option. Now we will only get the most basic parameters to configure our print.





When we pass the cursor through each of the settings, a brief help appears that explains what this adjustment does.

Values that we will use for the printing of the part:

Quality

Layer Height: 0.2mm

The printers bring by default a nozzle (nozzle) 0.4mm wide. The optimal value between quality and maximum print speed is 0.2mm

Walls

Wall line count: 2

2 is an optimal value for parts that do not require significant stress. An outer perimeter and an inner perimeter will be created.

Increasing the value will print more layers of interior perimeter that will increase the thickness and with it the rigidity of the piece. On the contrary, the piece will consume more material.

Top or bottom

Top layers: 3

Bottom layers: 3

As in wall lines, the greater the number, the greater the rigidity. We leave as default 3.

Fill

Fill density: 20%

Fill pattern: Cubic

The filling allows to create an interior structure in the piece that lightens it and simplifies the material used while giving rigidity to the piece.

We will leave as default 20% in most cases. And as a Cubic fill pattern.

Material

Print temperature: 200 degrees

Print plate temperature: 60 degrees.

The temperature will depend a lot on the material with which we are going to print, the brand and even the model.

By default, as it will be printed in PLA, the range of values goes from 190 degrees to 220. We'll leave it at 200.

The temperature of the bed favors the adhesion of the piece to it. A default value of 60 degrees will be set.

Velocity

Print speed: 40mm/s

The speed of printing will allow us to finish prints more quickly. It depends on the type of printer (of how rigid it is or if it is direct extrusion or Bowden) that we can increase the value.

The higher the speed, the less definition in the piece.

It is recommended not to exceed a value of 40mm/s for printers with direct extrusion and 60mm/s for Bowden type printers.

Travel

Enable retraction: On

Print Board Z-Hop: On

The retraction what it does is that when the printer has to continue printing at another point, it collects the filament so that it does not fall along the way.

It will remain activated and the jump in Z, so that the car climbs a little in the displacement and does not collide with any printed part.

Cooling

Enable print cooling: On

Fan speed: 100%

Keep the fan always on and at 100% in the case of PLA printing so that the layers solidify with greater speed.

Support

Generate support: Off.

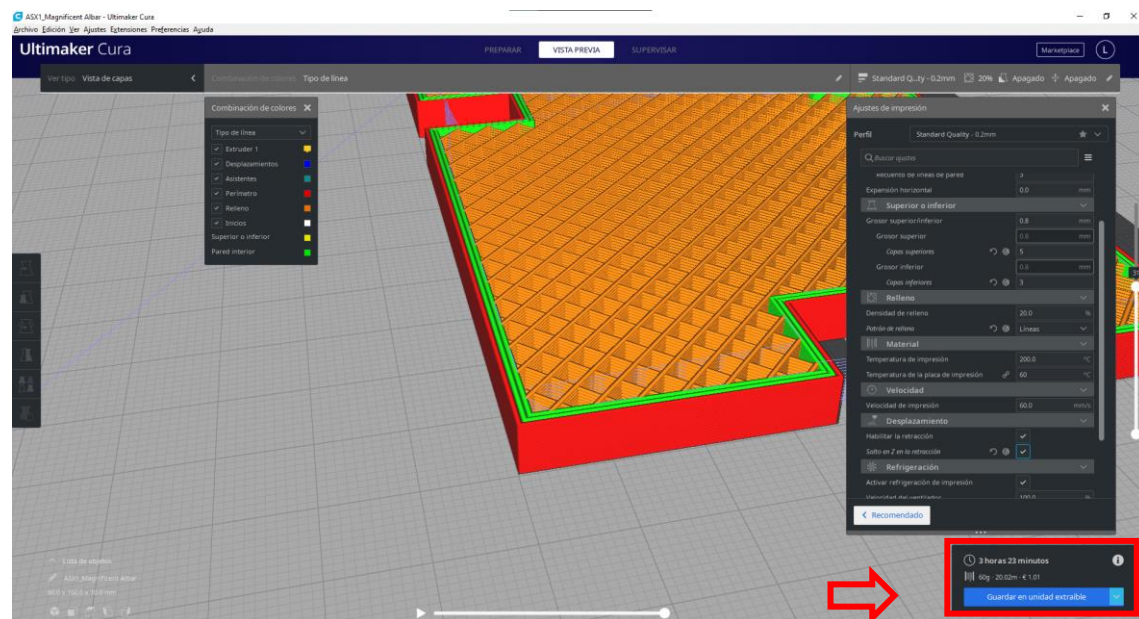
Adhesion to the printing plate

Type of adhesion of the printing plate: None.

When the piece has little contact with the base, we can generate an auxiliary perimeter that allows us to improve the adhesion of the piece.

In this case, we will have it deactivated since the piece has 100% of the base in contact with the bed.

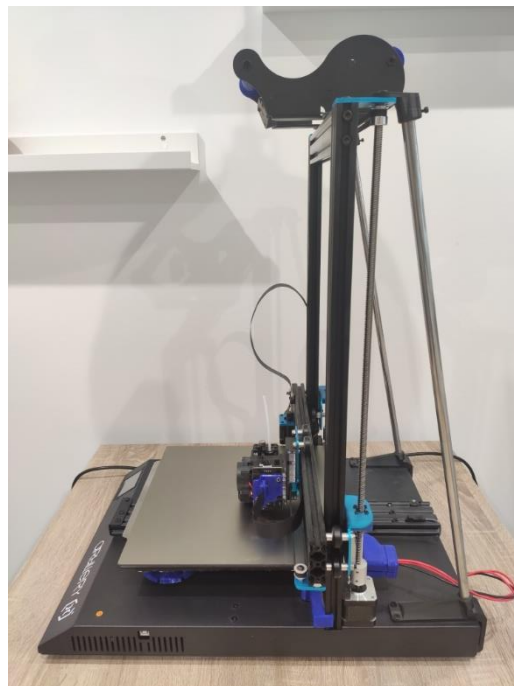
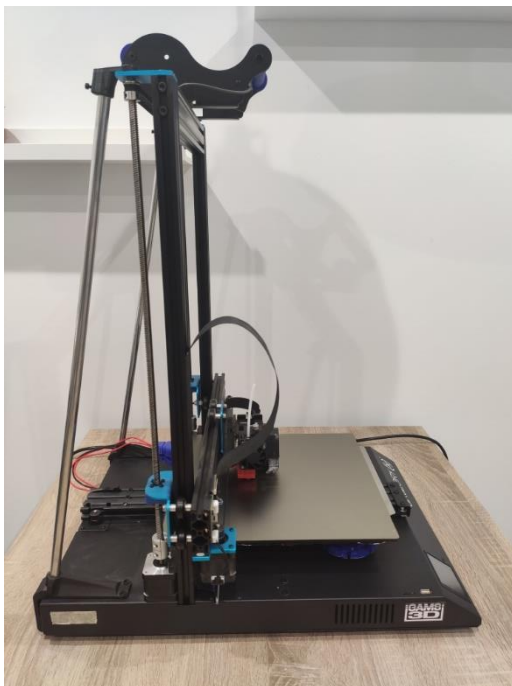
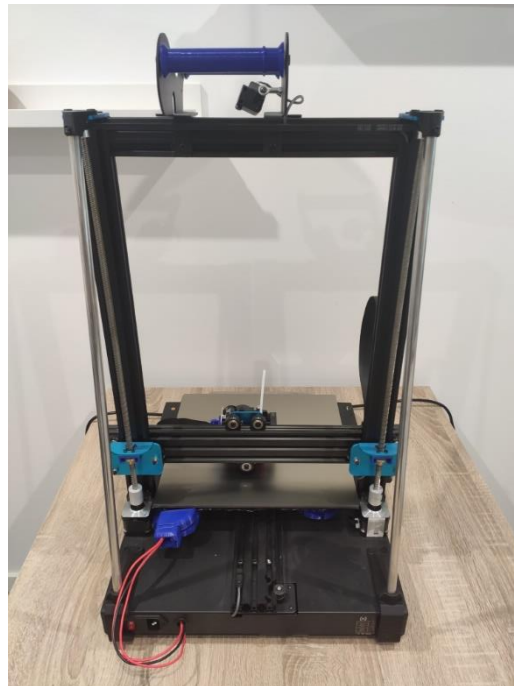
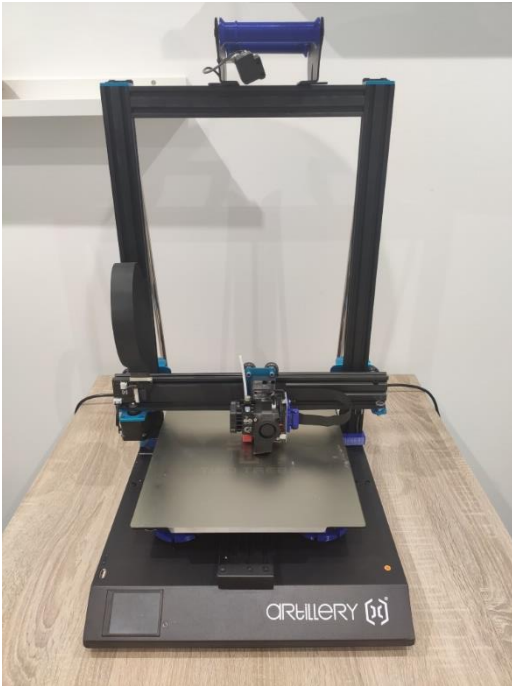
Once we have the parameters adjusted, we will insert a pen drive in our computer, the program will recognize it and we will export our print, a Gcode will be generated that we will insert in our printer. We can also save it on our computer and then place it on a pen drive.



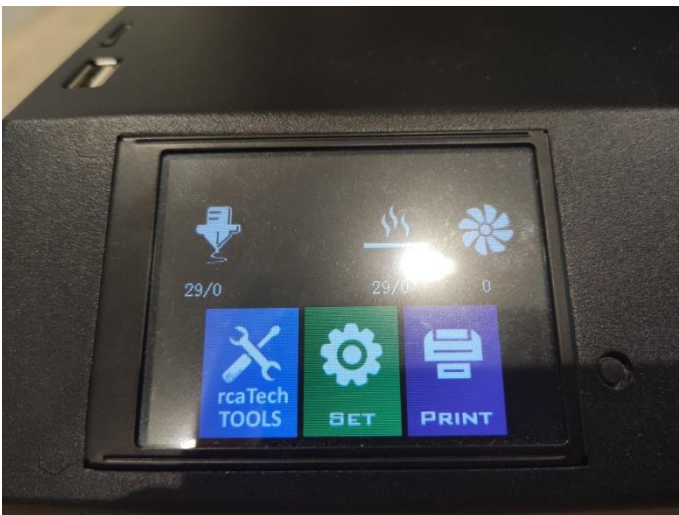
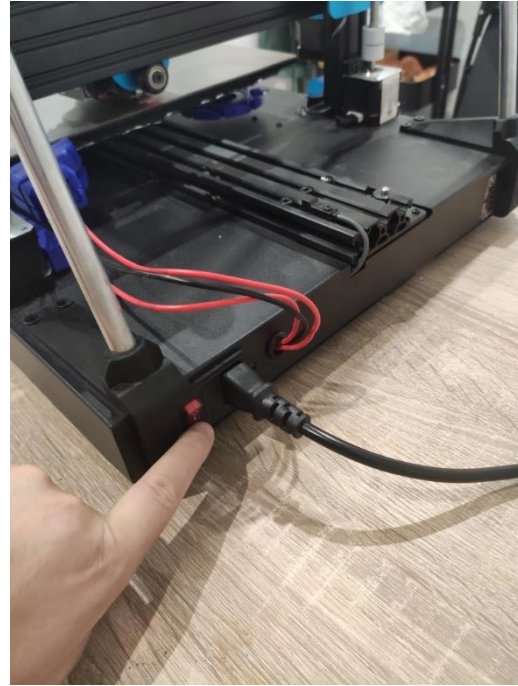
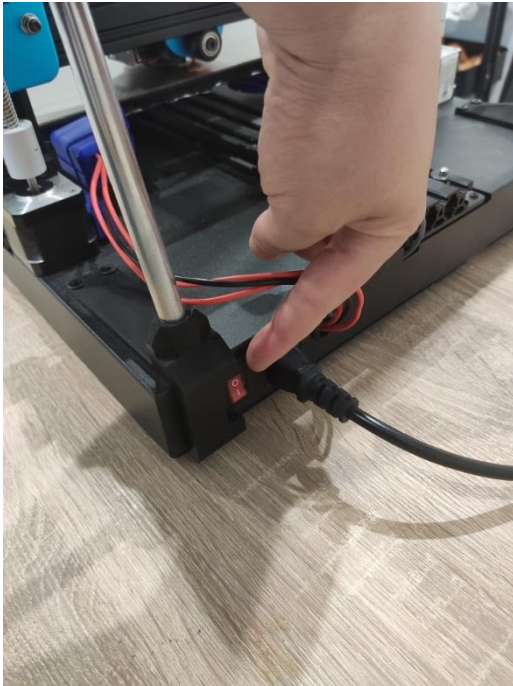
3.3. 3D PRINTER

Print process

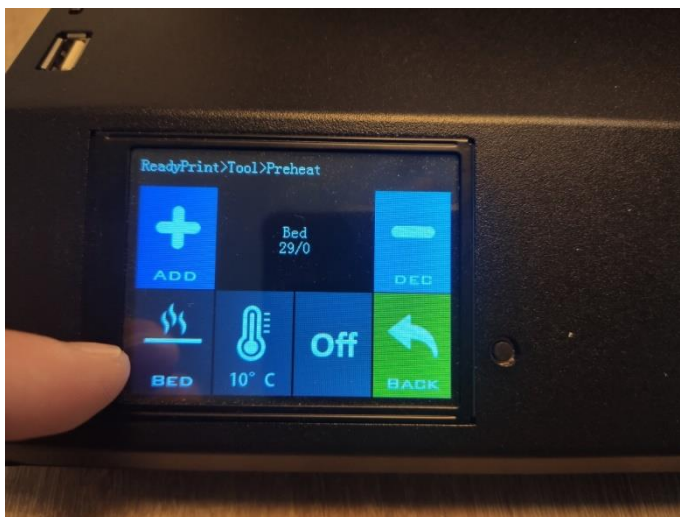
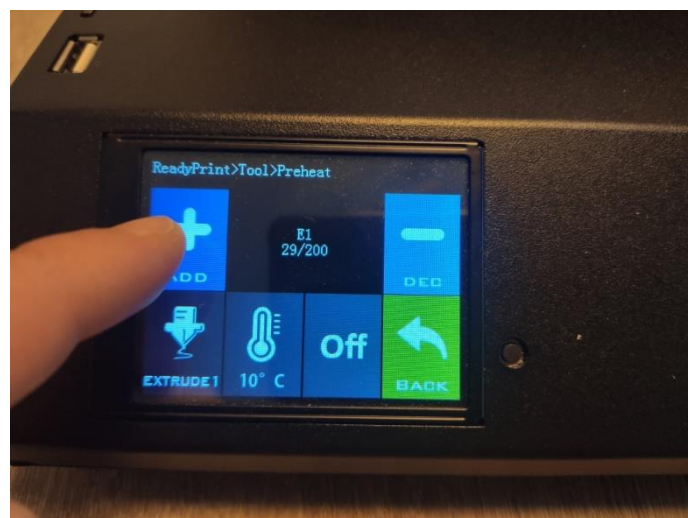
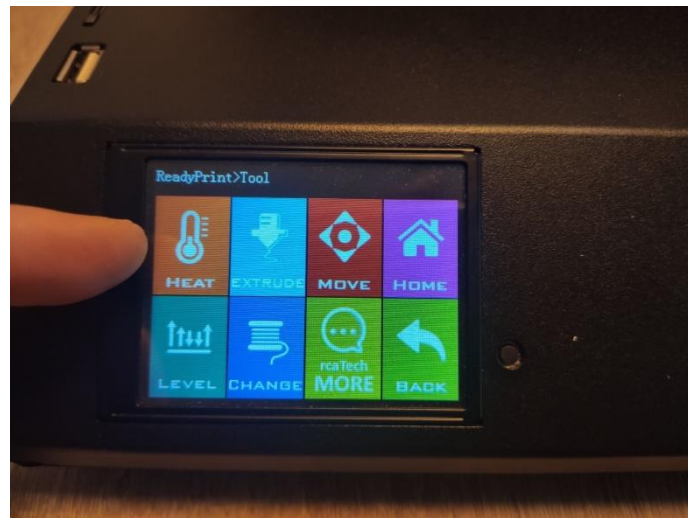
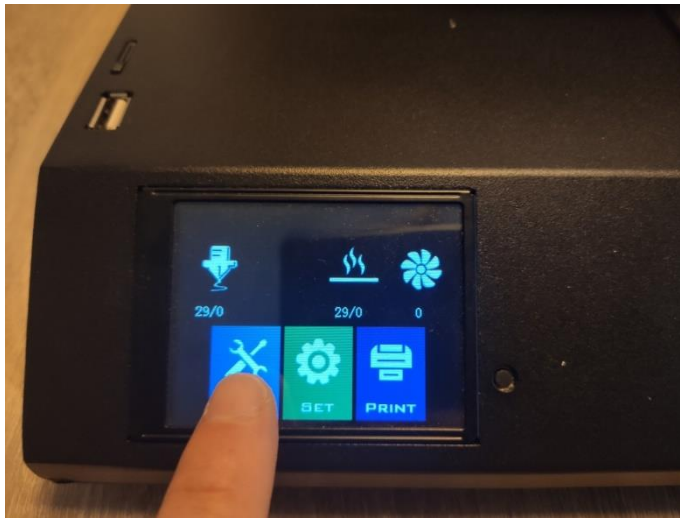
This process may vary depending on the type of printer we have. The process is the same for all in general, but they can vary the interface of the printer menu or, depending on the type we have (direct or Bowden), the way to introduce the filament). In this case we perform the process with an Artillery X1, which is a printer with direct extrusion.



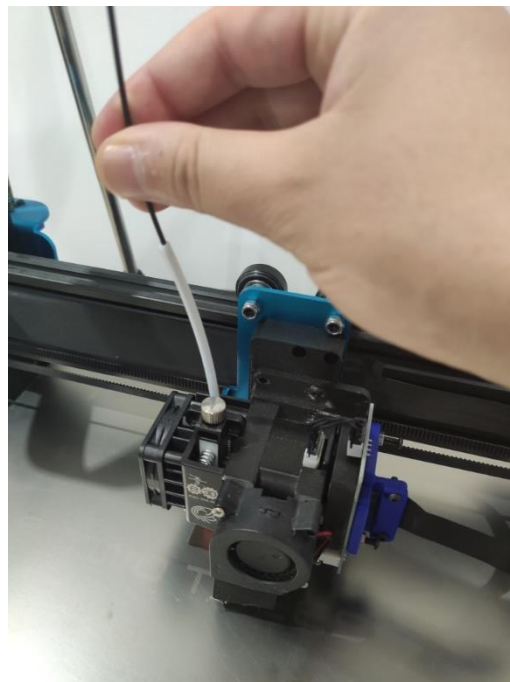
Turn on our printer



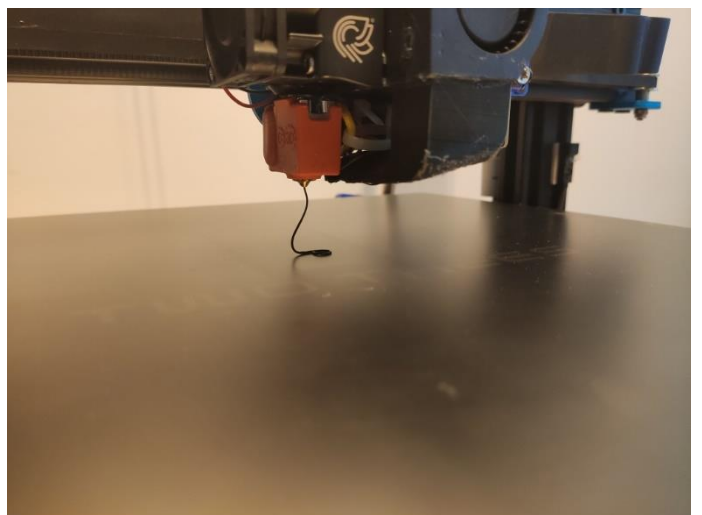
Preheat the extruder and printer bed (the base)



Insert the filament. The use of PLA is recommended for the ease of printing and as it is a biodegradable plastic.

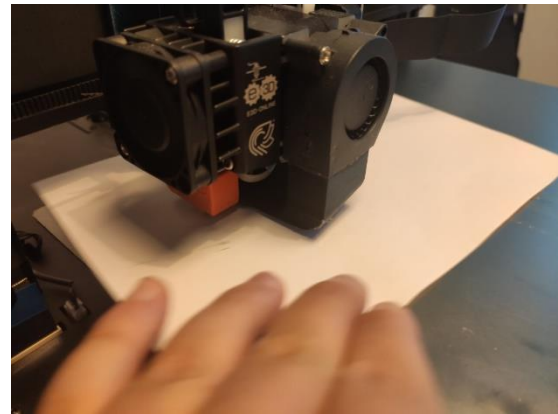
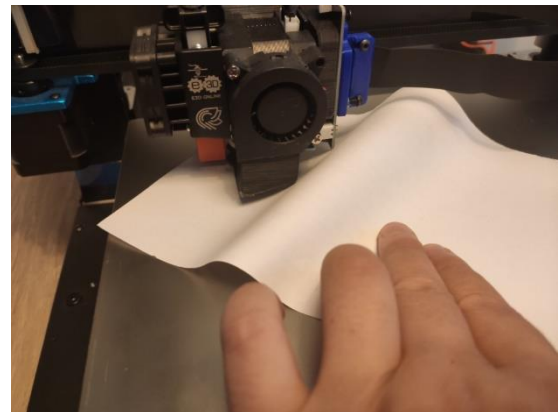


Extrude until it exits through the nozzle. To do this from the menu of the screen, we will indicate the extrusion.



Level the printer bed:

To do this we will navigate through the menu of the printer's screen and give it in "level". We will choose each of the points and, for each one, we will put a sheet of paper between the mouthpiece and the bed, we will turn the wheel that is in each of the corners of the bed until we find a point where the paper offers some resistance when we move it, without stopping. We will repeat the process in each of the corners and at the center point.

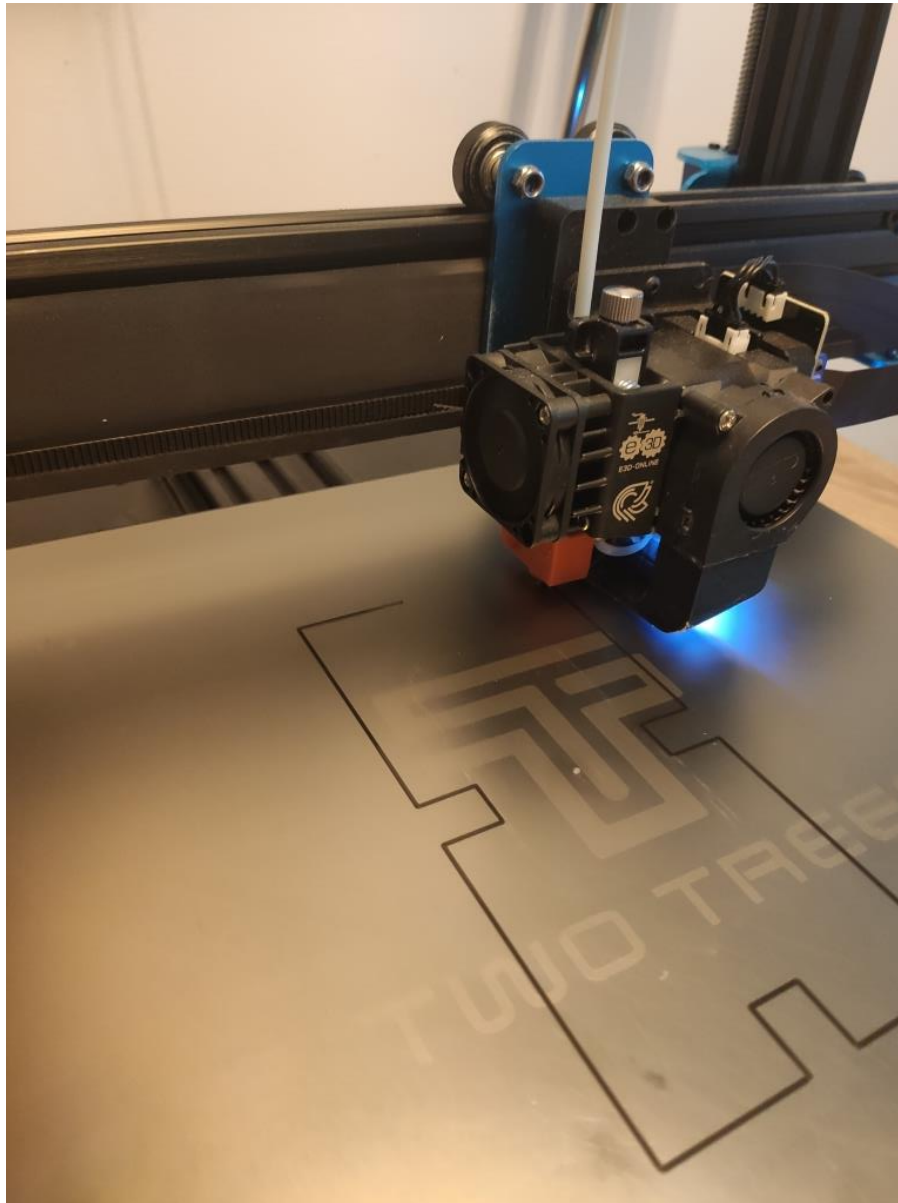


We will insert the Pen drive or the SD card, depending on the type of printer we have.

Navigate through the menu of the printer screen, press the "Print" button, select the desired file and hit "Confirm".



After a few seconds the printer will start printing.



4. ATTACHED DOCUMENTATION



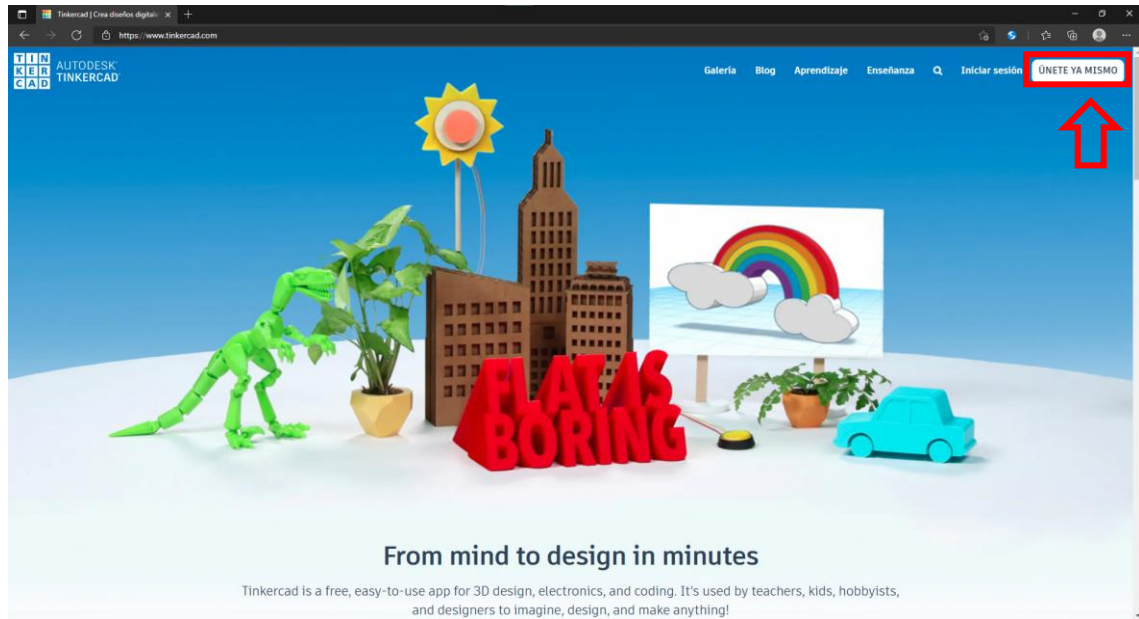
4.1. TinkercAD. Account creation

Tinkercad is Online. Works by logging in with an Autodesk account.

1- Go to <https://www.tinkercad.com/>

The interface will be similar to the following shown.

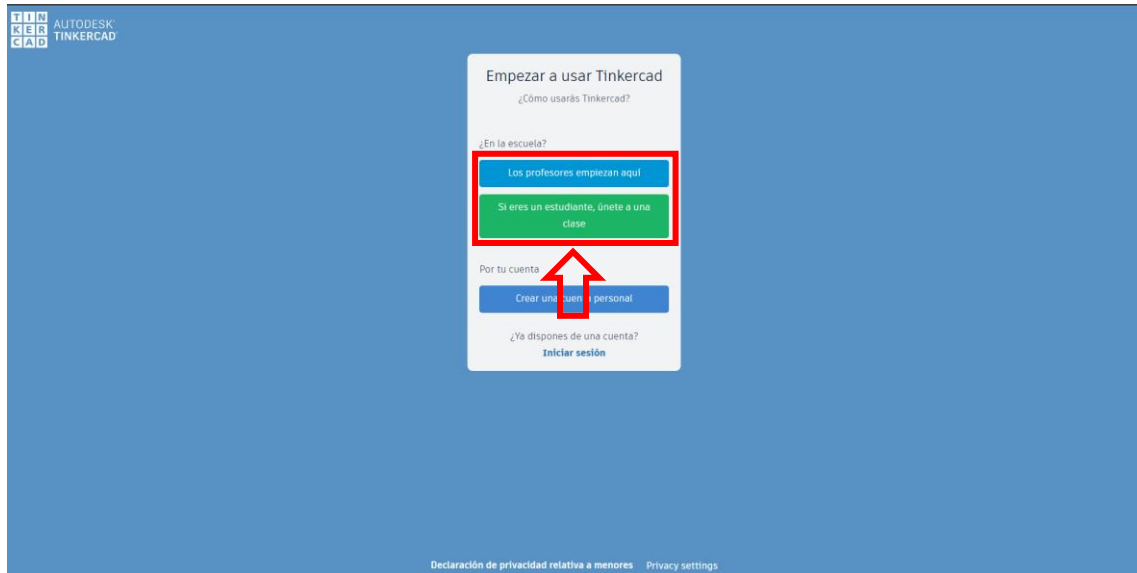
We'll have to go to the top right of the screen. Click on : "Login".



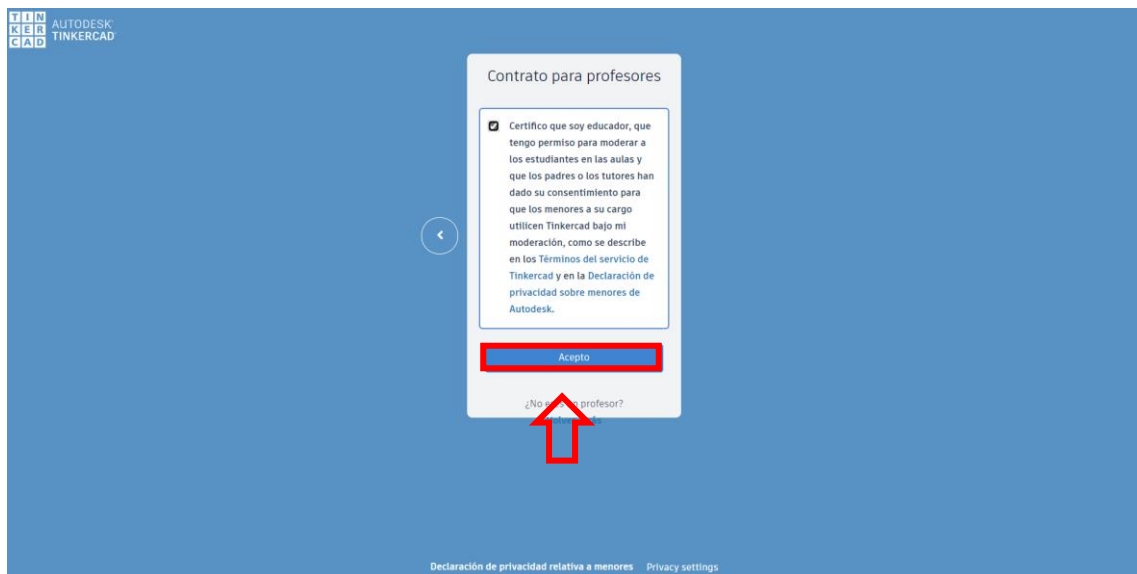
We will create an account depending on whether we are students, teachers or others.

The difference between teacher and student accounts is that the teacher account allows you to create Classrooms that students can join and share their projects.

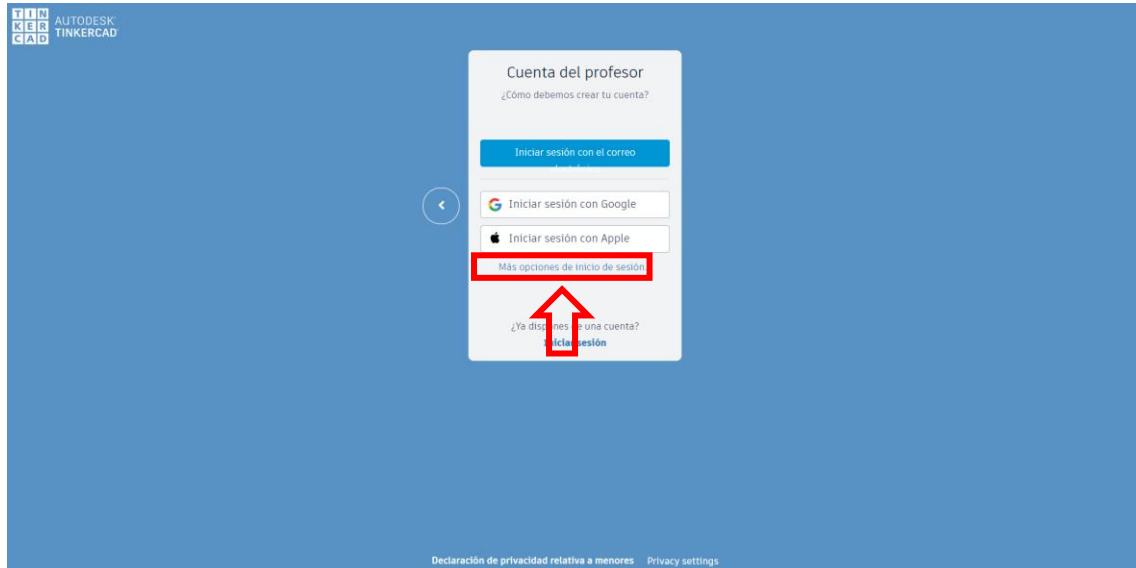
In the next window we will choose the link depending on the role.



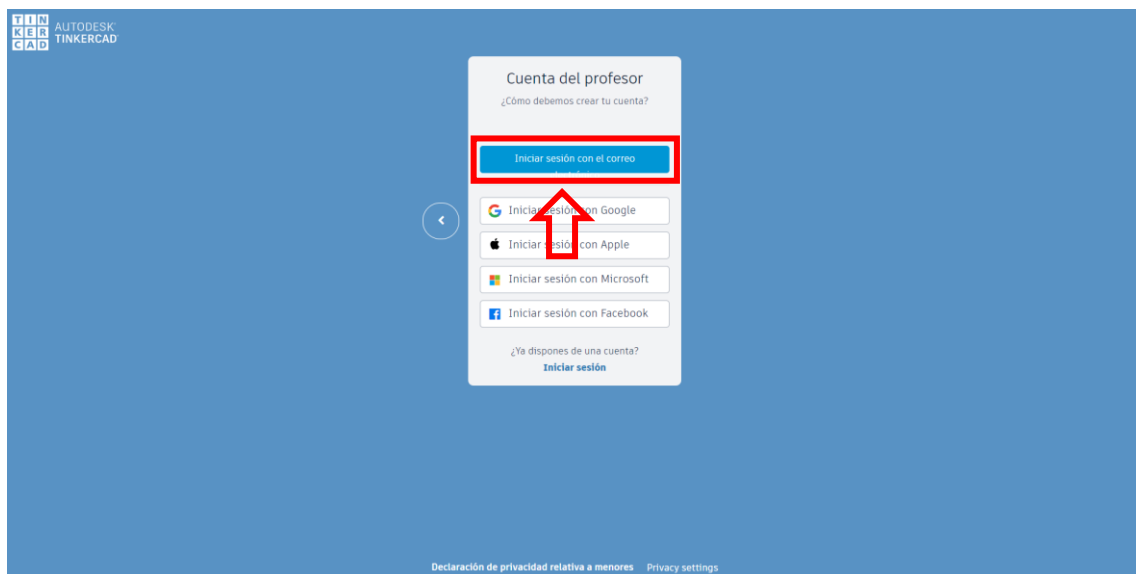
The next window asks us to accept the terms and conditions. Check the box where it says : "I certify that I am...", then click on "I accept".




Then, in the next window you will ask us for an existing email account with which to use Tinkercad. The first options that appear are, create an account from Autodesk 0. Create an account from an existing Gmail or Apple account. By clicking on the link "More login options...", we will also see the options to create an account from a Microsoft or Facebook email account.



Click on "Log in with email"



Crear cuenta 

País, territorio o región

Cumpléalos
 Mes Día Año

SIGUIENTE

[¿YA DISPONE DE UNA CUENTA? INICIE SESIÓN](#)

Su cuenta para todo lo relacionado con Autodesk
[MÁS INFORMACIÓN](#)

Crear cuenta

Acepto los [Términos del servicio de Tinkercad](#) y la [Declaración de privacidad de Autodesk](#)

CREAR CUENTA

[¿YA DISPONE DE UNA CUENTA? INICIE SESIÓN](#)

Su cuenta para todo lo relacionado con Autodesk
[MÁS INFORMACIÓN](#)

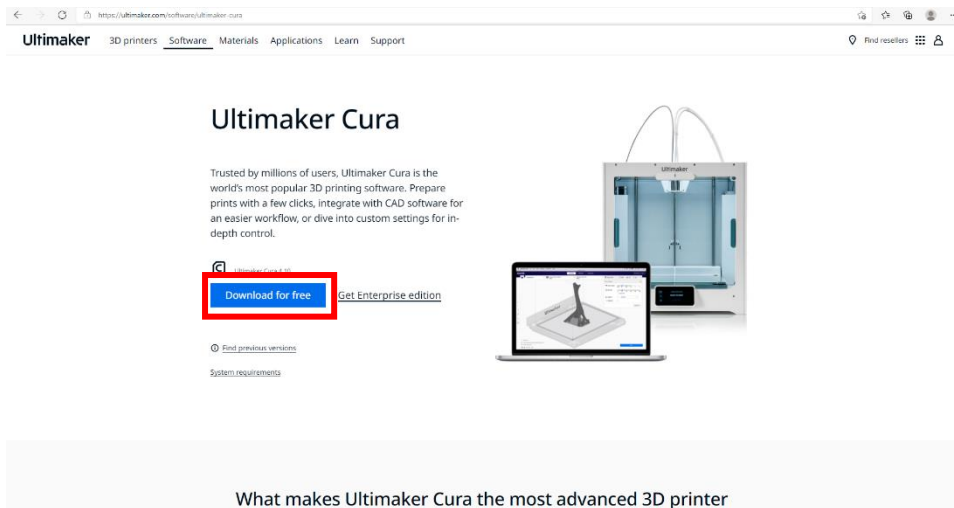


4.2. LAMINATOR. CURE. DISCHARGE AND INITIAL CONFIGURATION

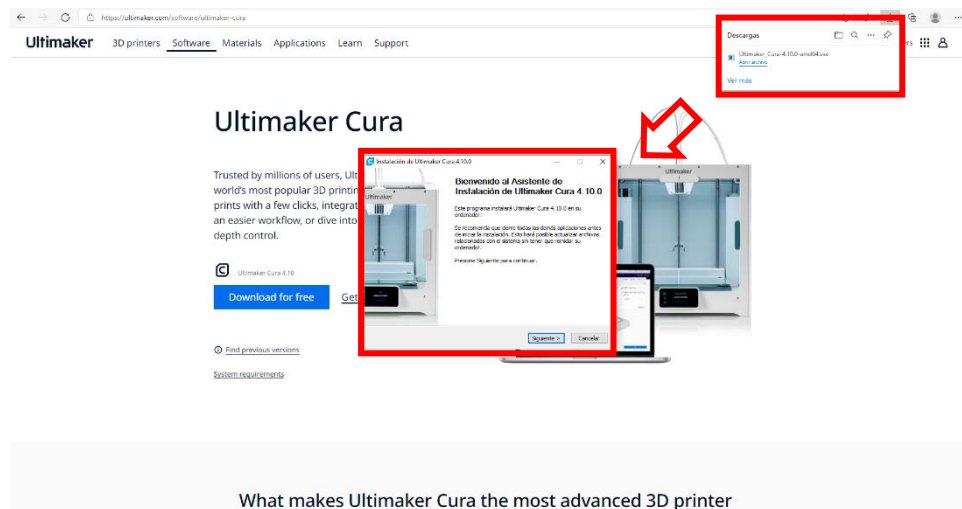
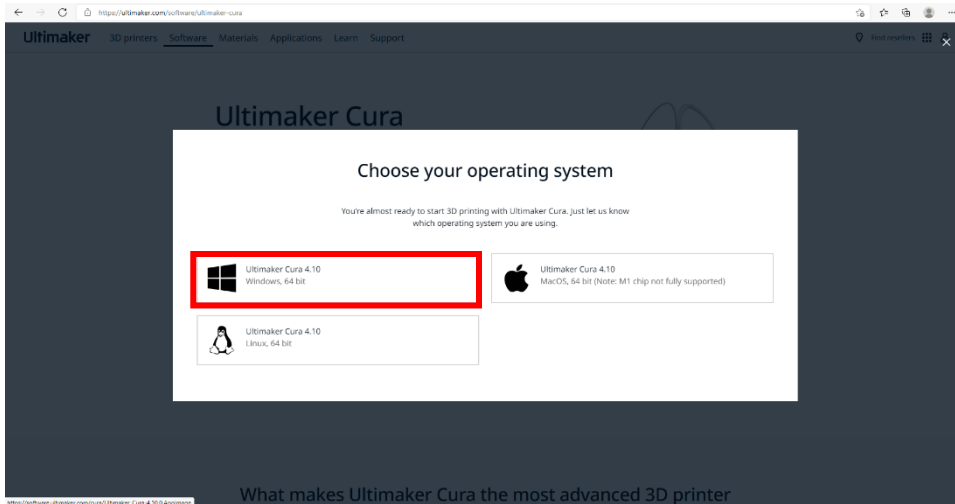
Software download

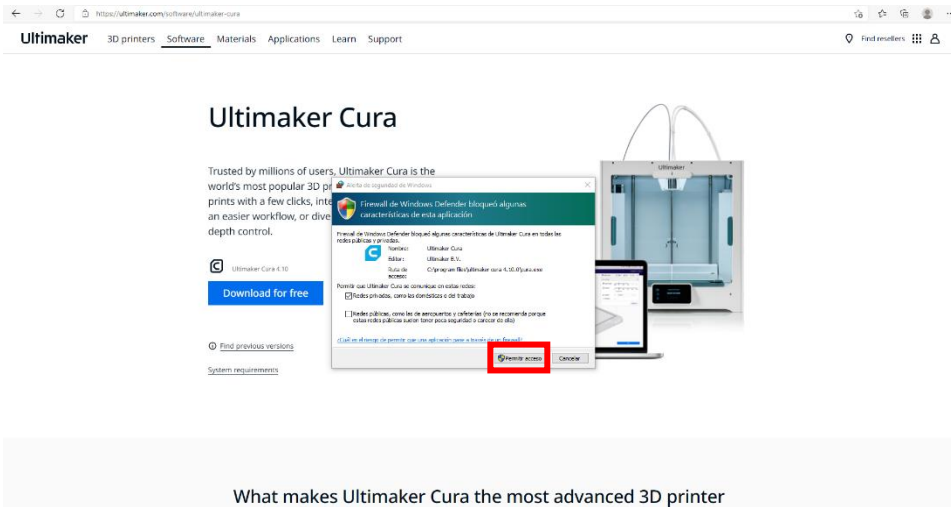
Go to: <https://ultimaker.com/software/ultimaker-cura>

Click on "Download for free"



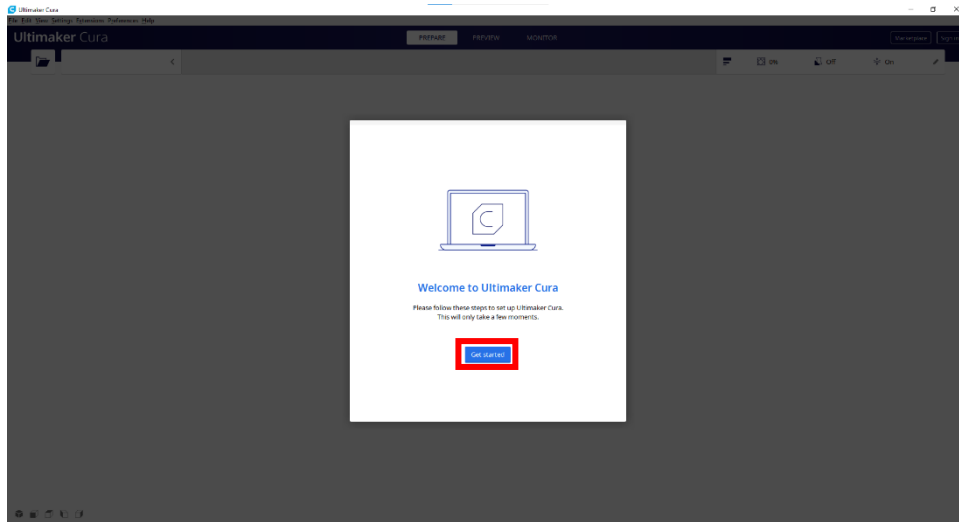
Choose your computer's operating system: Download, accept all steps and install. Once installed we run it for the first time. If the firewall window appears (in the case of Windows), we will give it to allow access.



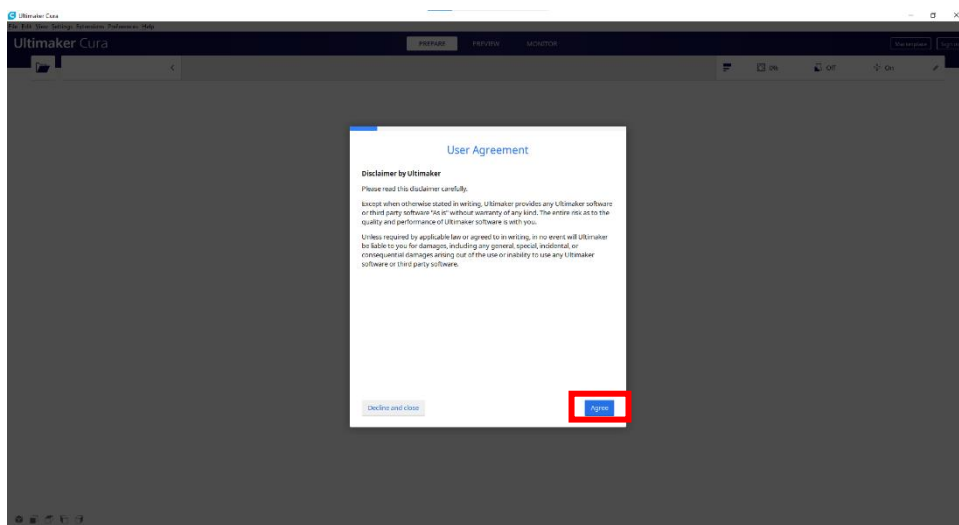


First Steps.

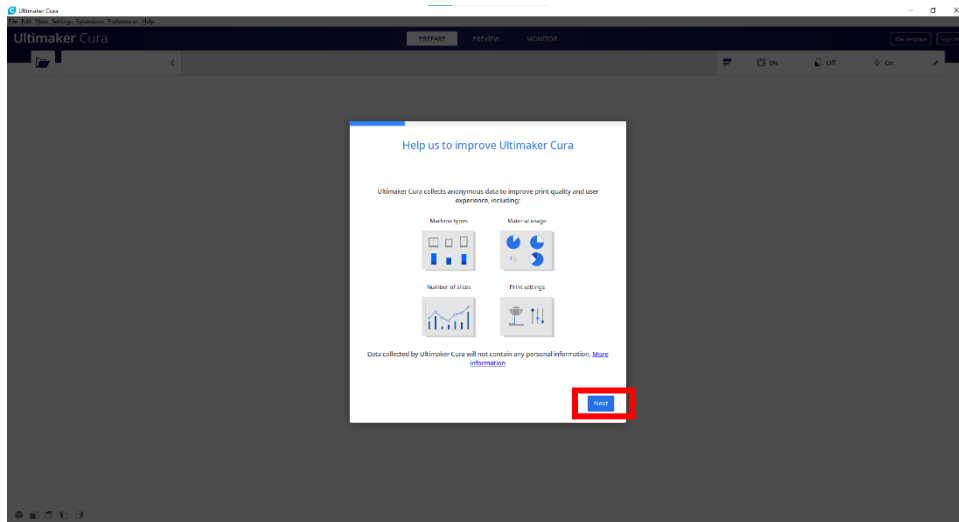
Once the program is downloaded the next step will be to configure our printer in the laminator, since it is possible that it does not come to us by default. We ran the program for the first time. A window will appear as shown below. Click on "get started".



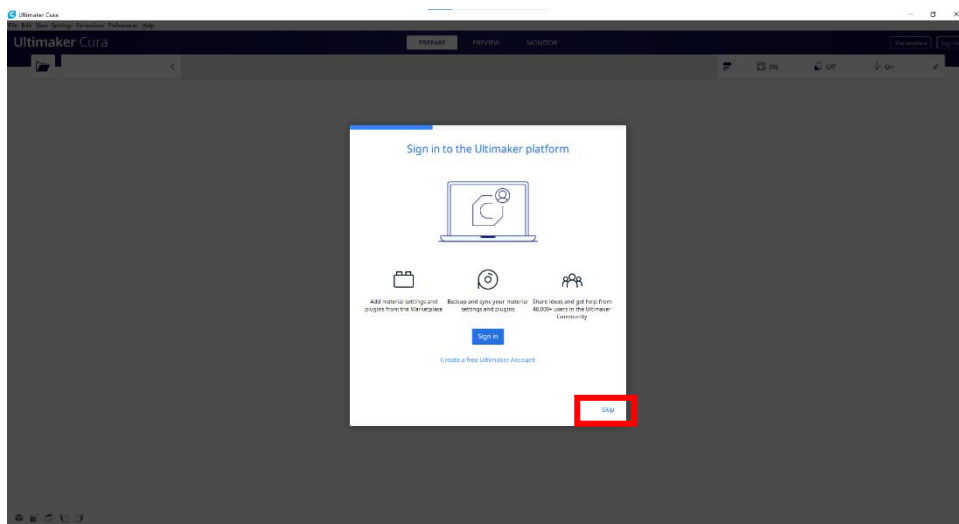
In the next window we will accept the terms and conditions.



We will also accept the following window.



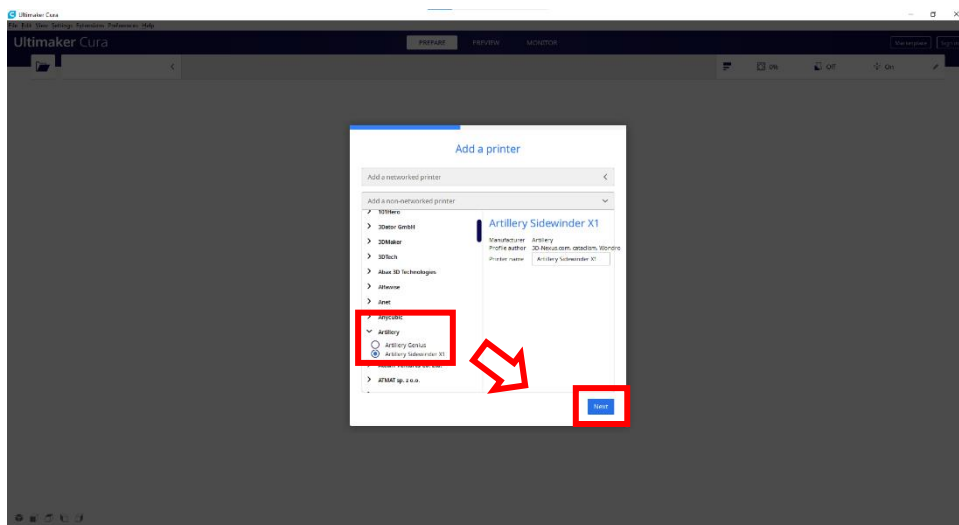
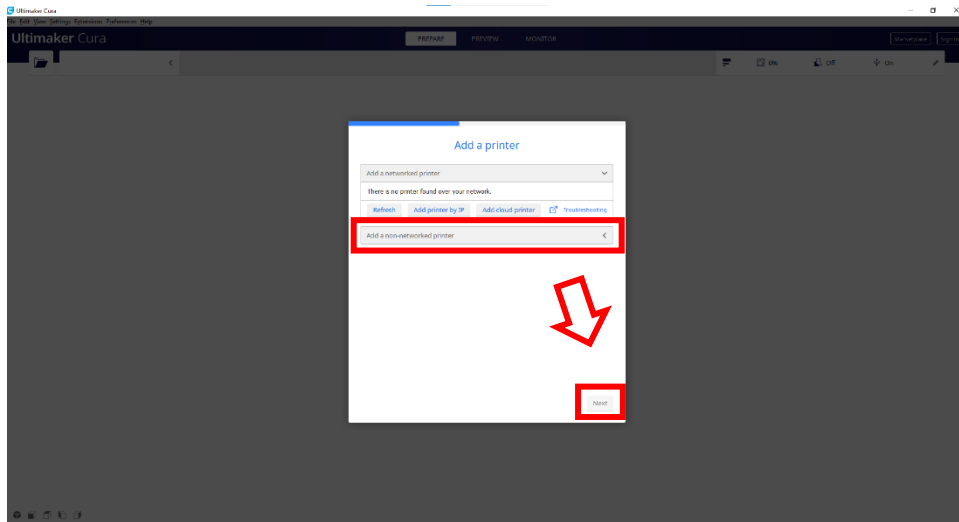
The next window asks us to log into the ultimaker platform, click on "skip":



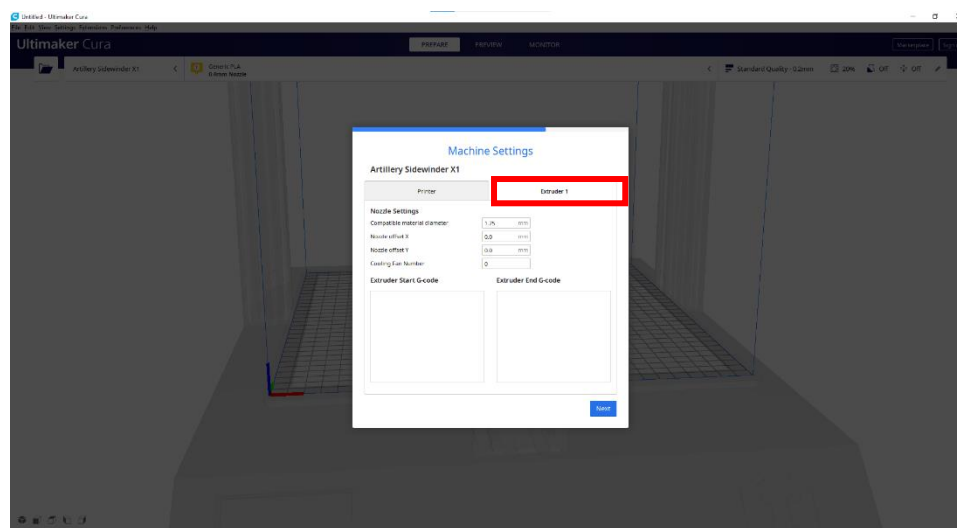
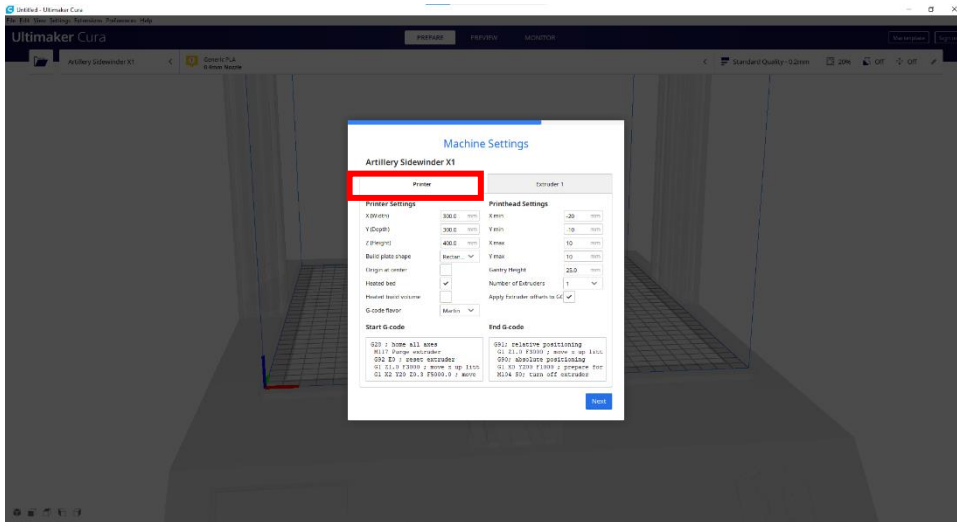
Printer configuration

The next window asks us to add a printer. We can add a network printer or a printer that is not networked, as is our case. We will display the menu of "add a non-networked printer", we will look for the make and model of our printer.

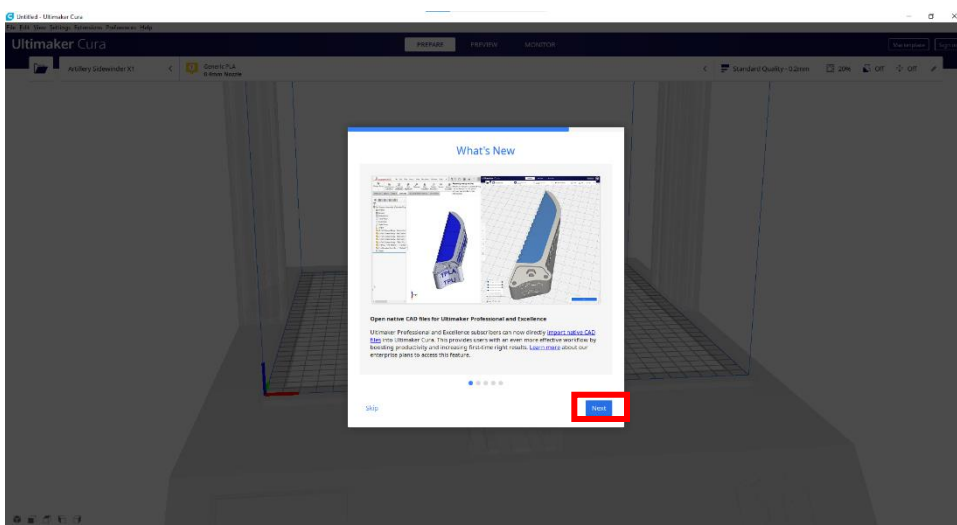
(for this example the X1 artillery will be used)



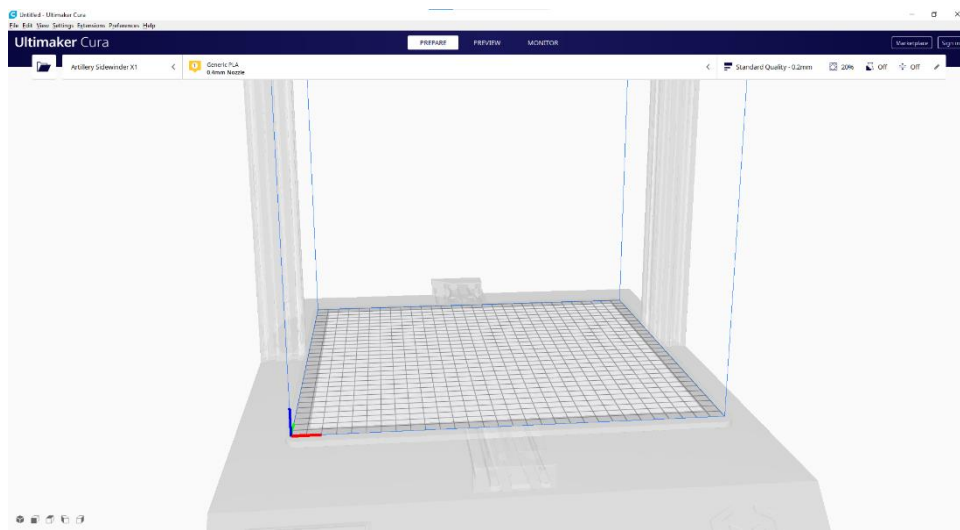
Ultimately, we will check that the default parameters that appear to us are correct: that the measurement of the base of our bed coincides with those of the printer in the printer tab and that in the extruder tab the filament diameter that appears is 1.75mm.



Finally, once we click on "next", we will see the window that announces the news of this version. We'll click to "Skip" and then to "finish".



We have already prepared our laminator.



4.3. 3D FDM PRINTERS

There are mainly 3 types of printers: FDM, Resin and Powder.

For this case we will use the FMD type printer for the following reasons:

- Lower princing.
- Ease of creation of parts.
- Ease of use.
- Greater ease of repair.
- Higher print volume.

Types of FDM printers

FDM printers are distinguished into two groups:

- Direct extrusion printers (the extruder is in the same block where the material is melted)
- Bowden type printers (the extruder that pushes the filament is separated from the block that melts the material).

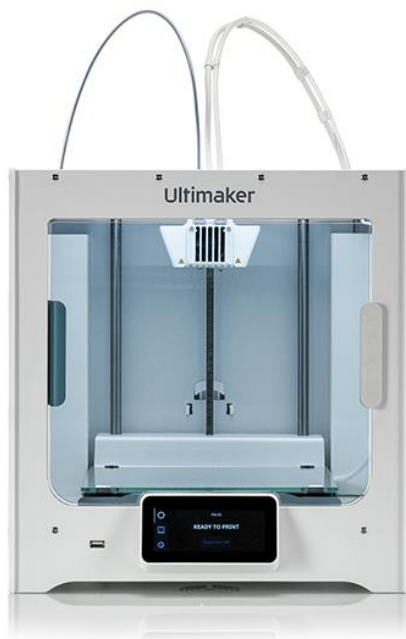


Brands and recommendations.

There are many brands on the market: Anycubic, Ultimaker, Artillery, Prusa, BQ, Creality, Anet, etc.

Depending on the brand, the printer is sold fully assembled and ready to print or sold pre-assembled, where we will perform the last assembly step to start using it.

Next, we will make a recommendation of several printers with different price ranges:

1- Ultimaker S3:

Printer fully assembled and ready to use. It is focused for professional use and allows the printing of a multitude of materials by default.

It has self-leveling of the bed.

Its price is approximately 4000€ and can be purchased directly through its website:

<https://ultimaker.com/es/3d-printers/ultimaker-s3>

2- Anycubic Vyper:



Medium profile printer, recommended for educational use. It has self-leveling of the bed, and a large navigation screen.

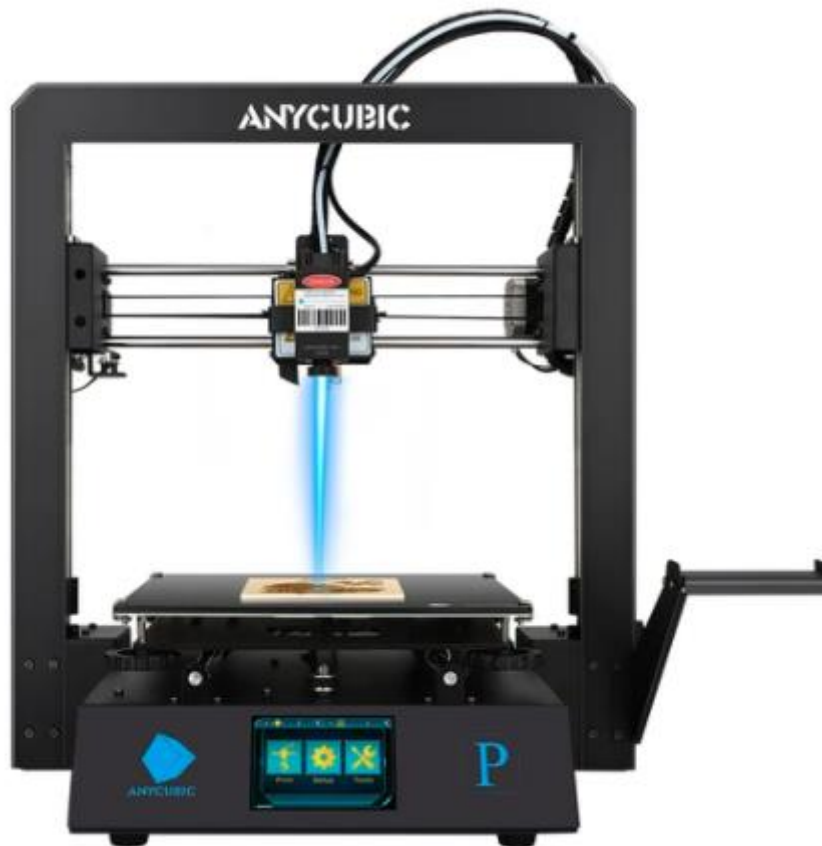
It is a pre-assembled printer, where we will only have to assemble the bridge containing the extruder with the base of the printer.

Its print volume is 245mm(L)×245(W)×260mm(H).

Its current price is approximately 304€ and can be purchased directly through its website:

<https://www.anycubic.com/products/anycubic-vyper>

3- Anycubic Mega Pro



Medium profile printer, recommended for educational use. It does not have self-leveling of the bed built into the printer itself, but it brings with it a device that can be connected and helps us to level it.

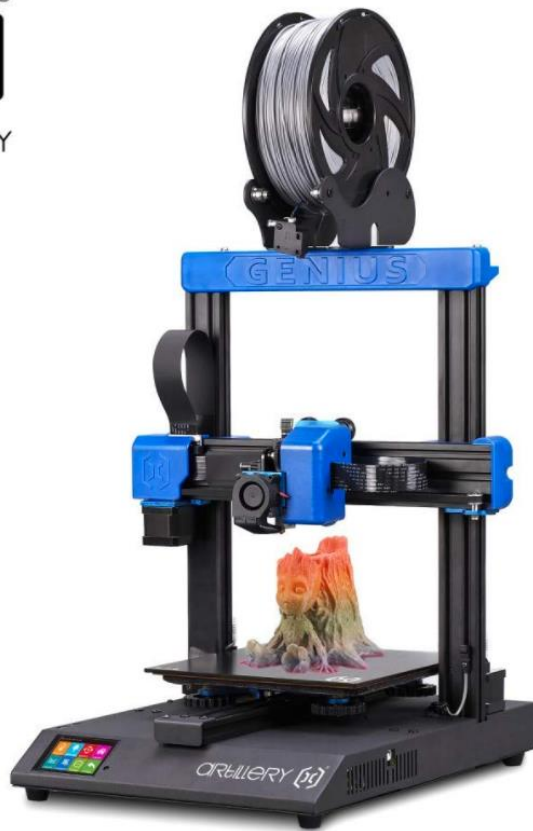
Its print volume is 210mm(L)×210(W)×205mm(H).

It is a pre-assembled printer, where we will only have to assemble the bridge containing the extruder with the base of the printer.

Its current price is approximately 278€ and can be purchased directly through its website:

<https://www.anycubic.com/collections/anycubic-mega-3d-printers/products/mega-pro>

4- Artillery Genius



Low profile printer, recommended for recreational use. No self-levelling bed. The screen menu of the printer has a very intuitive and friendly interface.

Its printing volume is 220mm(L)×220(W)×250mm(H).

It is a pre-assembled printer, where we will only have to assemble the bridge containing the extruder with the base of the printer.

Its current price is approximately 220€ and can be purchased mainly through Bangood and aliexpress:

Brand link: <https://artillery3d.es/artillery-genius/>

Link buy Aliexpress:

https://es.aliexpress.com/item/4000244336412.html?aff_fcid=0a1673d307ef45a9b8288db81a954cd2-1626930756121-03618-_d7Aw7my&aff_fsk=_d7Aw7my&aff_platform=link-c-tool&sk=_d7Aw7my&aff_trace_key=0a1673d307ef45a9b8288db81a954cd2-1626930756121-03618-_d7Aw7my&terminal_id=8ae35cb2cf7744318c997d3b517e7fb7&tmLog=new_Detail

Link buy Bangood:



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https://es.banggood.com/Artillery-Genius-DIY-3D-Printer-Kit-220+220+250mm-Print-Size-with-Ultra-Quiet-Stepper-Motor-TFT-Touch-Screen-Support-Filament-Runout-DetectionandPower-Failure-Function-p-1568218.html?akmClientCountry=ES&p=AO190136620922201907&custlixnkid=876712&cur_warehouse=ES&ID=48036

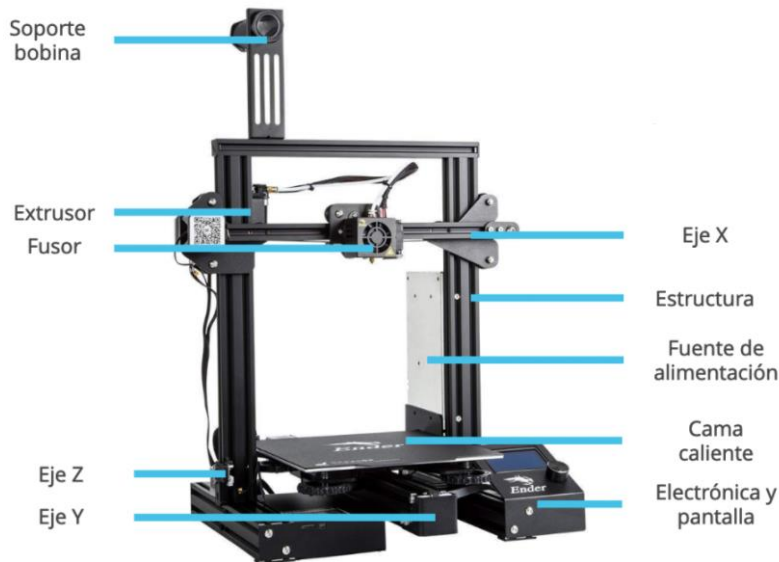
Video of the final assembly of the printer:

<https://youtu.be/tDYlkgxURxw>

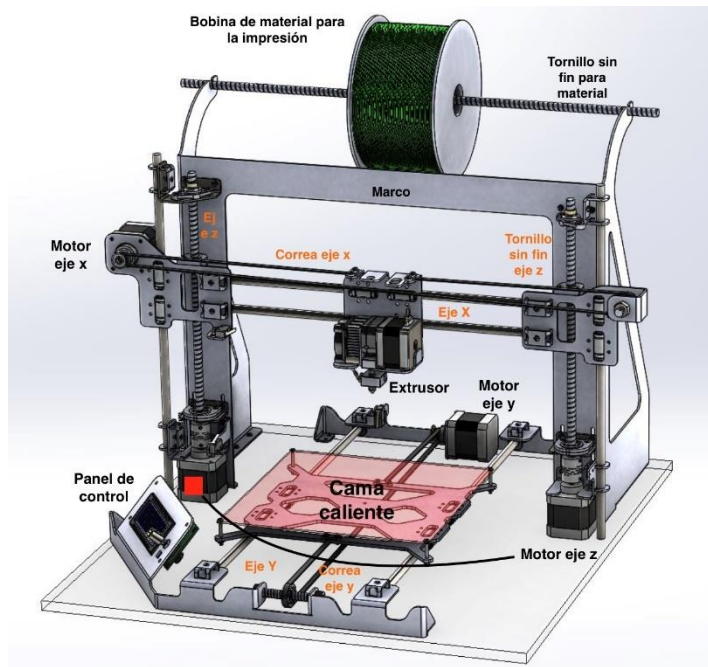


Parts of the 3D Printing

Parts of the Bowden-type FDM printer.



FDM printer parts direct extrusion.



5. Other resources

For an overview of all possibilities that 3D Print can offer, you can find more documentation in:

[15 Things You Didn't Know About the 3D Printing Industry - YouTube](#)

Websites dedicated to the sharing of user-created digital design files:

[Thingiverse - Digital Designs for Physical Objects](#)

[Cults - Descarga modelos 3D gratis para impresoras 3D \(cults3d.com\)](#)

Troubleshooting Guide to 19 Common 3D Printing Problems

[Troubleshooting Guide to 19 Common 3D Printing Problems | Part One – Geeetech Blog](#)

[Troubleshooting Guide to 19 Common 3D Printing Problems | Part Two – Geeetech Blog](#)

3D Printing Materials Guide

[Ultimate 3D Printing Materials Guide | Simplify3D](#)

