Key Action: KA2: Cooperation for Innovation and the Exchange of Good Practices, KA201 - Strategic Partnerships for school education
Project name: STEAM education and learning by Robotics, 3D and Mobile technologies - FabLab SchoolNet
Project No.: 2018-1-LT01-KA201-047064

INTELLECTUAL OUTPUT 6 - LEARNING MODULES AND COURSE ON FABLAB SCHOOL NET ENABLING TECHNOLOGIES

Output Type: Course / curriculum – Pilot course / module	
Activity Leading Organisation	2 EPAL TRIKALON
Participating Organisations	UNIVERSITATEA "DUNAREA DE JOS" DIN GALATI CONSIGLIO NAZIONALE DELLE RICERCHE FabLab Palermo APS

Due Submission Date:	28/01/2019
Actual Submission:	30/10/2021
Project Number	2018-1-LT01-KA201-047064
Instrument:	Strategic Partnerships for school education
Start/Finish Date of Project:	01.11.2018 – 31.10.2021
Duration:	36 months

Abstract	
This IO has the aim of applying the pedagogical model developed in O1, in pilot course that will be held by the 2 EPAL in Greece. During the course the materials collected in the repository in O3 will be used. Teachers will also implement the teaching model developed in O4. The assessment procedures will be also employed to evaluate the learning experiences of this pilot course and fix the issues detected before the courses that will be deployed in Bulgaria and Lithuania.	
Output Type: Course / curriculum – Pilot course / module	
Activity Leading Organisation	2 EPAL TRIKALON
Participating Organisations	UNIVERSITATEA „DUNAREA DE JOS" DIN GALATI CONSIGLIO NAZIONALE DELLE RICERCHE FabLab Palermo APS

CONTENT

Course curriculum

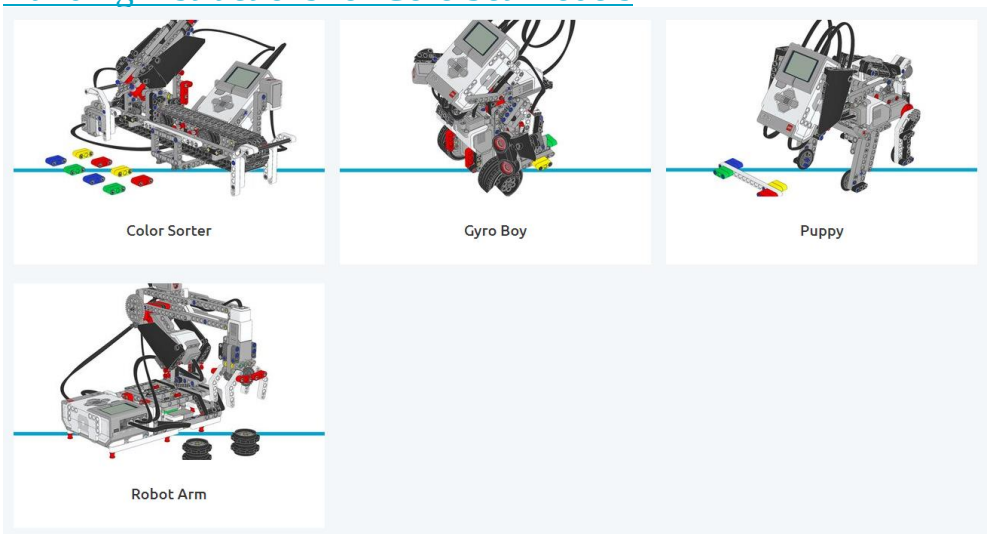
Part 1. Robotics

LEGO® MINDSTORMS® Education EV3
Building Instructions & Program Descriptions

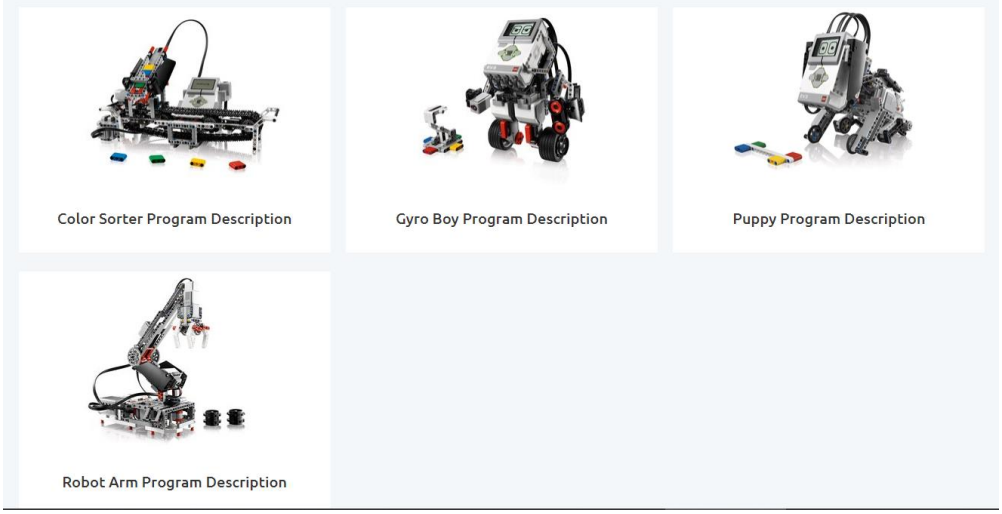
Building Instructions for Core Set Models
Program Descriptions for Core Set Models
Building Instructions for Robot Educator
Building Instructions for Expansion Set Models
Program Descriptions for Expansion Set Models
Building Instructions for Design Engineering Projects
Building Instructions for Space Challenge Set Models
Building Instructions for Science Models
Program Descriptions for EV3 Science Pack

https://education.lego.com/en-us/support/mindstorms-ev3/building-instructions

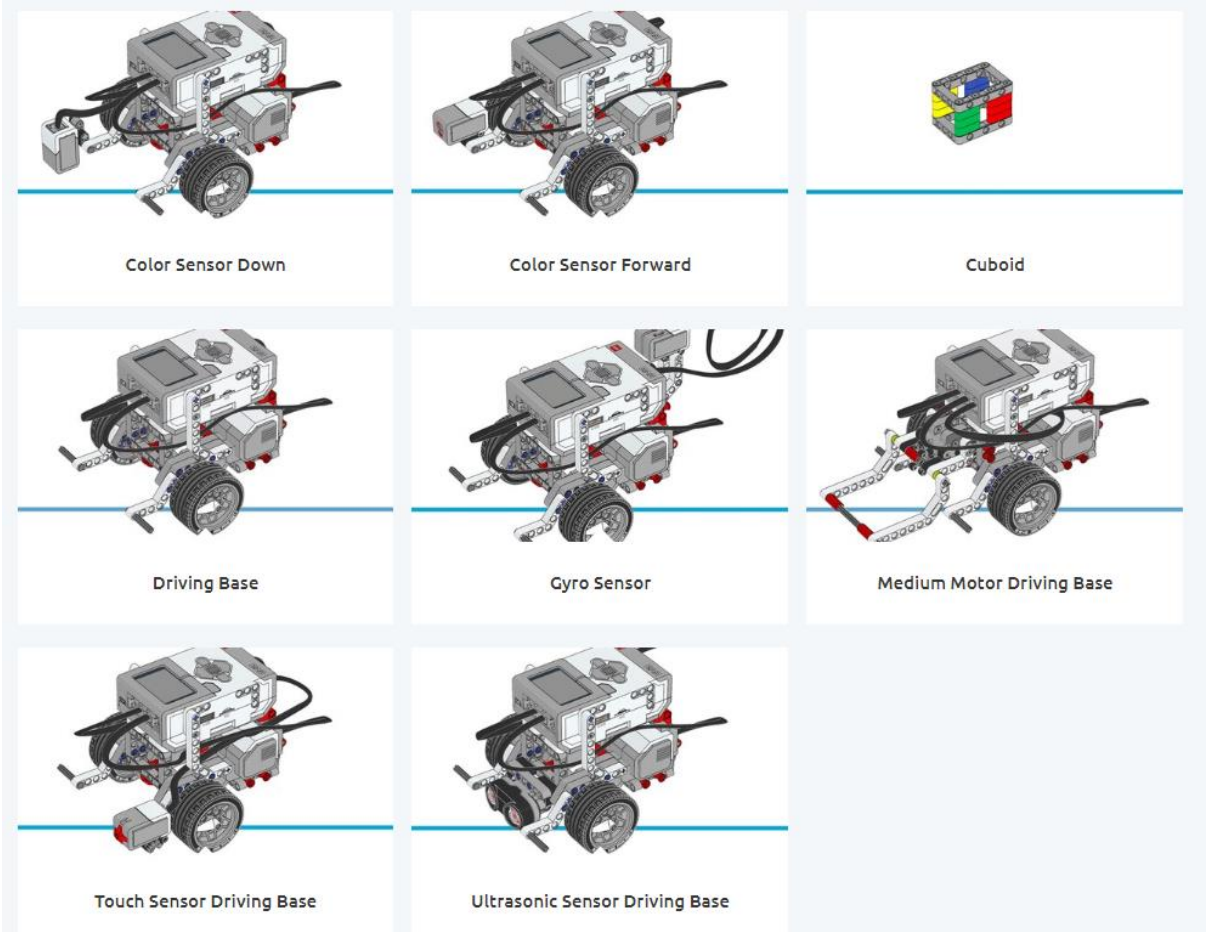
Building Instructions for Core Set Models



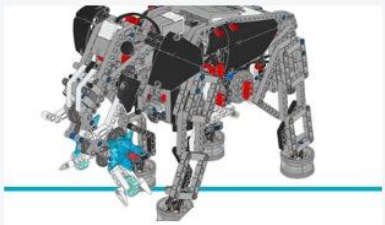
Program Descriptions for Core Set Models



Building Instructions for Robot Educator



Building Instructions for Expansion Set Models



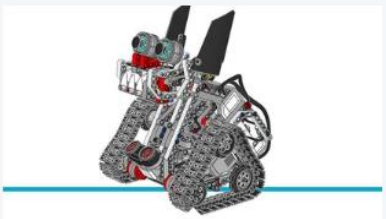
Elephant

Remote Control

Spinner Factory

Stair Climber

Tank Bot



Znap

Program Descriptions for Expansion Set Models

Elephant Program Description

Remote Control Program Description

Spinner Factory Program Description

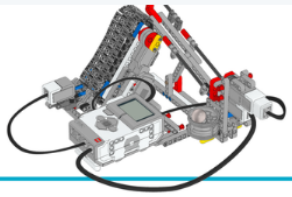
Stairclimber Program Description

Tankbot Program Description

Znap Program Description

Building Instructions for Design Engineering Projects

Anglerfish



Ball Conveyor

Ball Rest 1

Ball Rest 2

Ball Wheel

Bevel Bot

Bevel Gears

Catch

Chute

Color Sensor V1

Color Sensor V2

Color Squares

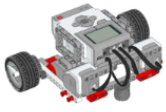
Cuboid

EV3 Frames

Eye

Flower

Foot



Gear Bot

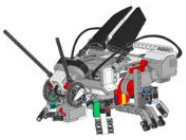
Gear Down

Gear Up

Gorilla

Grabber

Gyro sensor



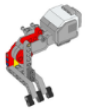
Insect

Jaw

Large Motor and Connector

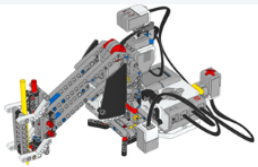
Large Motor and Wheel

Leg 1



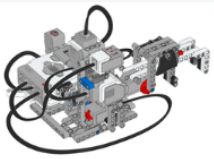
Leg 2

Leg 3

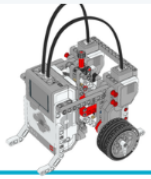


Pen arm

Pen Holder

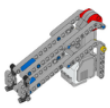


Pick and Place

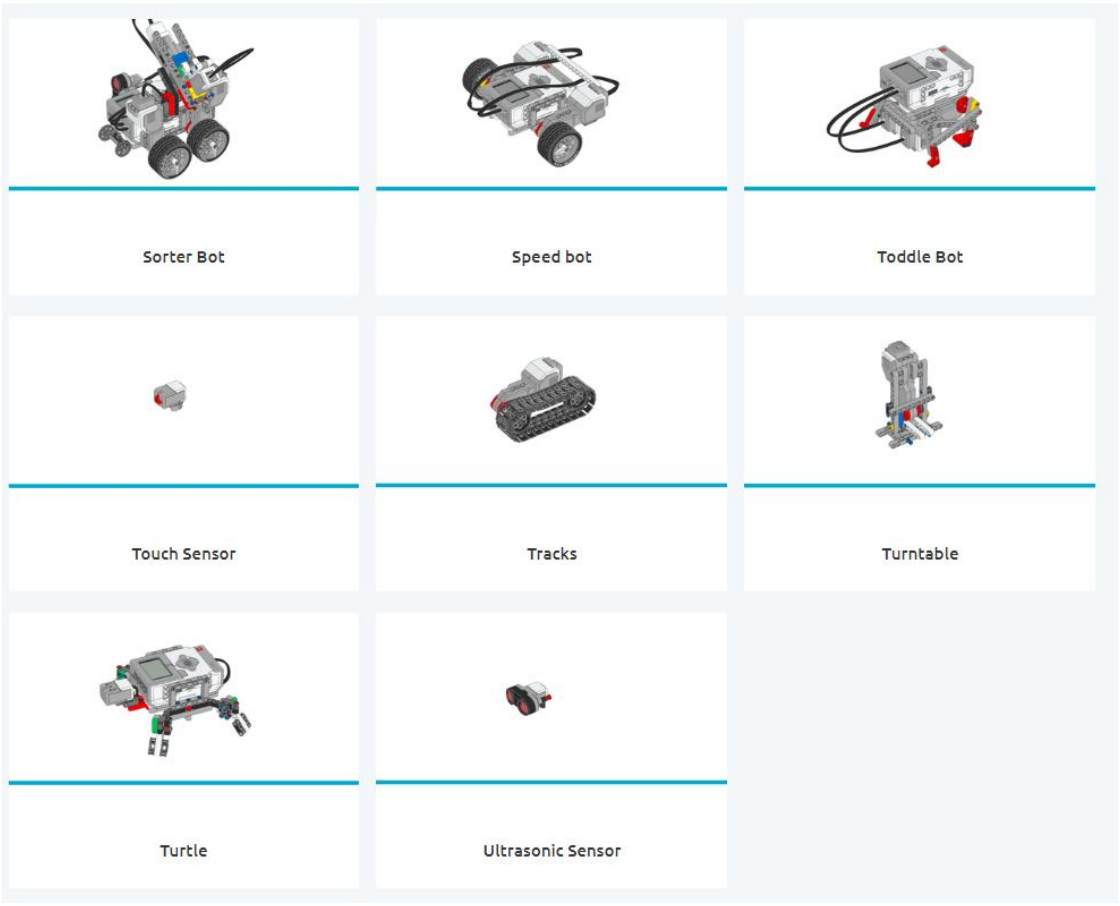


Plot bot

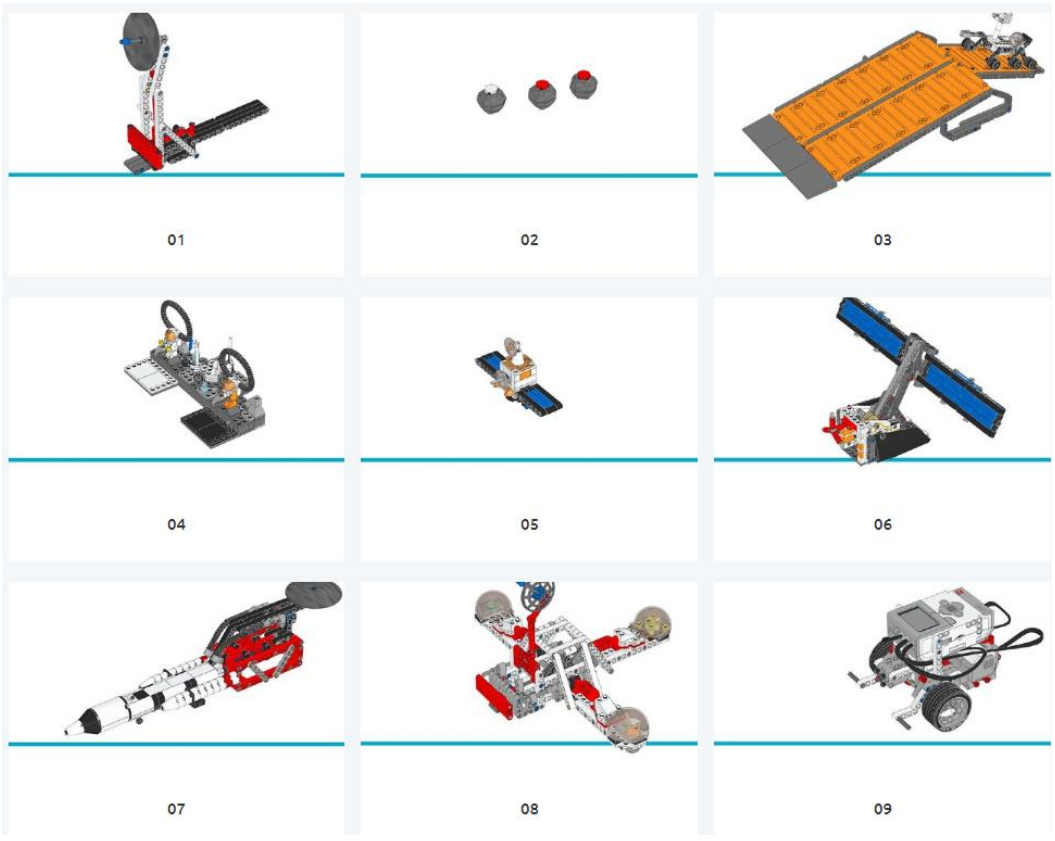
Ramp

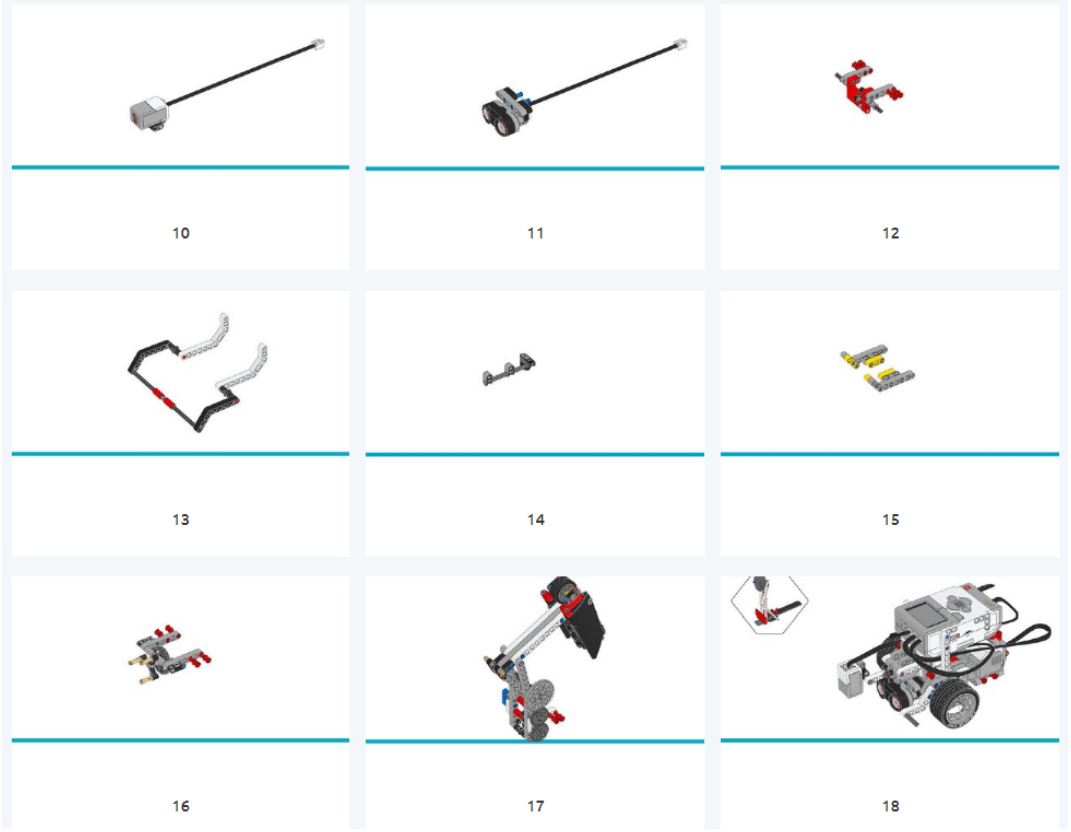


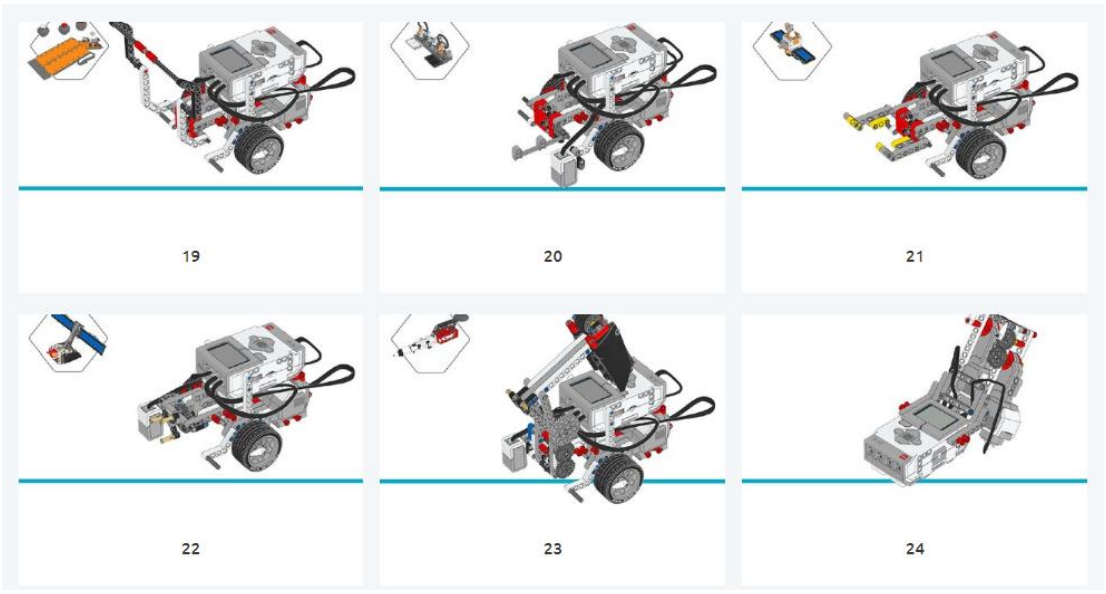
Seesaw



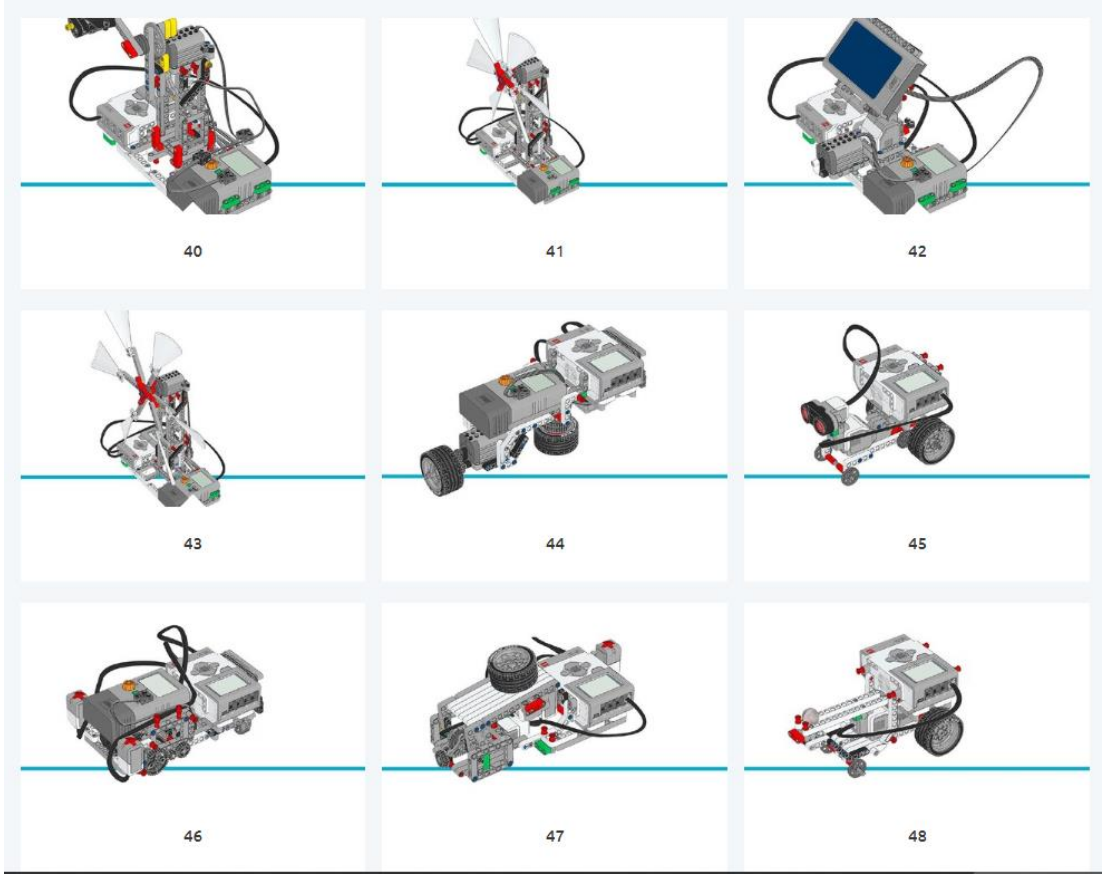
Building Instructions for Space Challenge Set Models

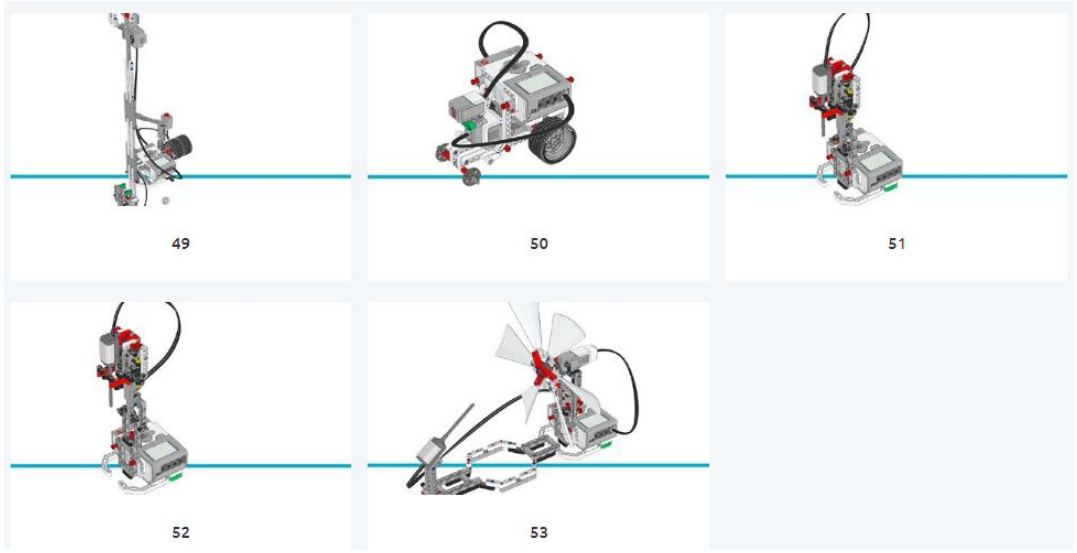






[Building Instructions for Science Models]





Program Descriptions for EV3 Science Pack

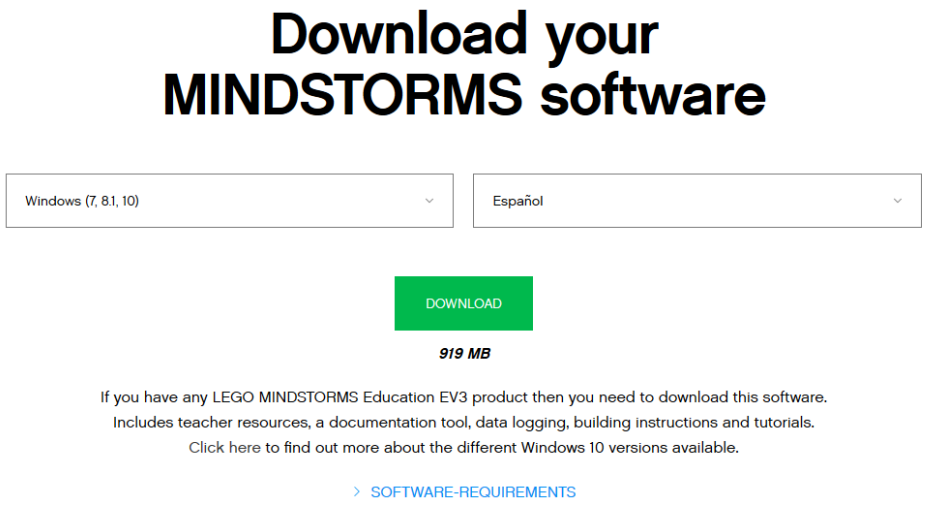
- Acceleration of Gravity
- Electric Vehicles
- Energy Transfer
- Friction
- Gears

- Inclined Plane
- Light Intensity
- Solar Panel
- Velocity
- Wind Energy

MINDSTORMS EV3 software

LEGO MINDSTORMS Education EV3:

https://education.lego.com/en-us/downloads/mindstorms-ev3/software



Explore eLearning

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LEGO® Education Academy

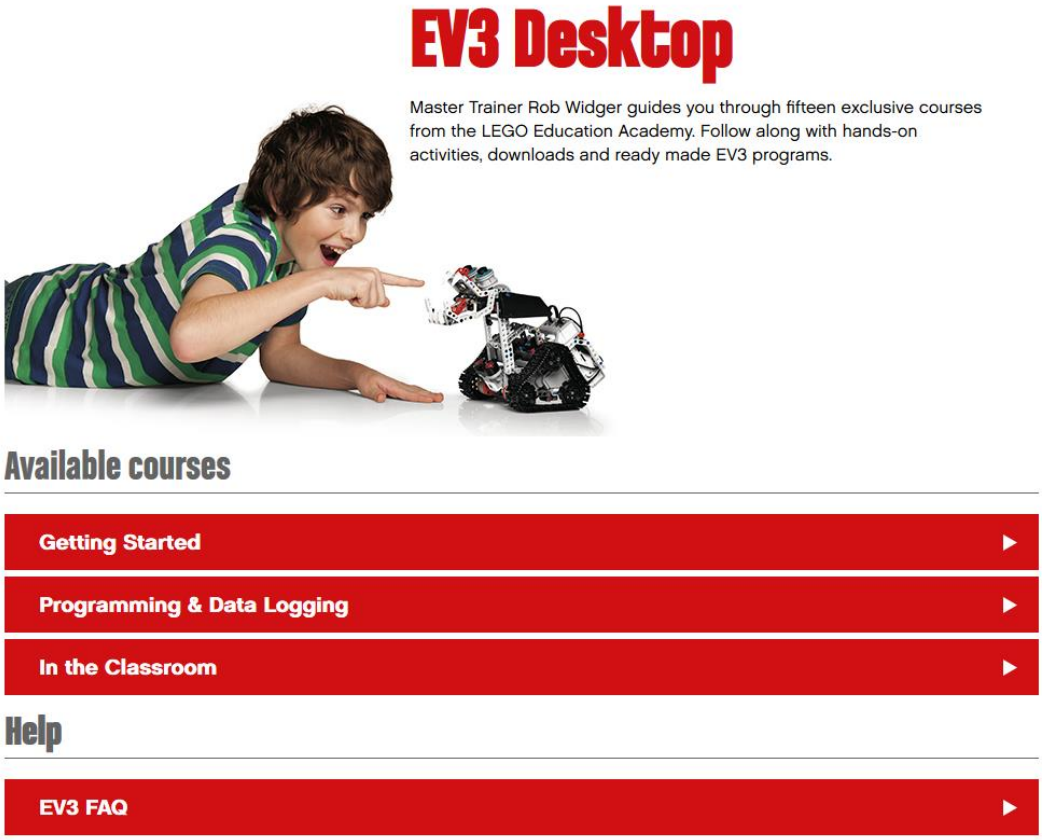
Enabling every student to succeed

Mindstorms EV3 Desktop Course

https://elearning.legoeducation.com/ev3

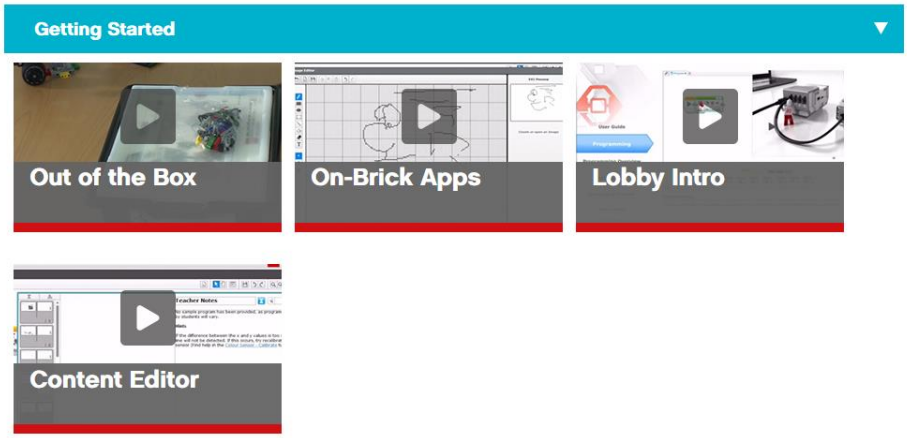
EV3 Desktop

Master Trainer Rob Widger guides you through fifteen exclusive courses from the LEGO Education Academy. Follow along with hands-on activities, downloads and ready made EV3 programs.

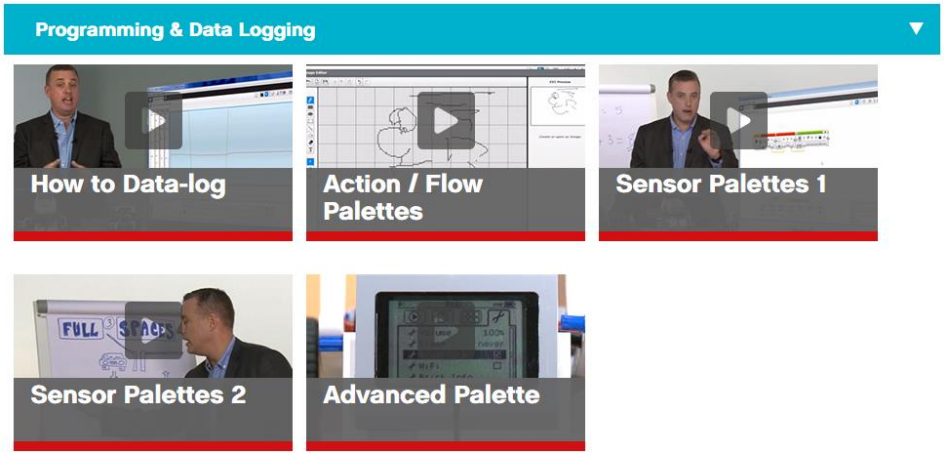


https://elearning.legoeducation.com/ev3-desktop

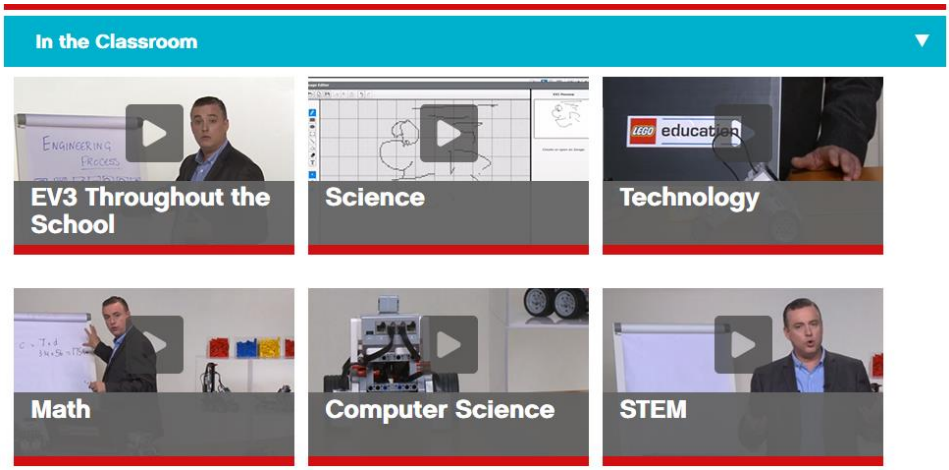
Getting Started



Programming & Data Logging



In the Classroom

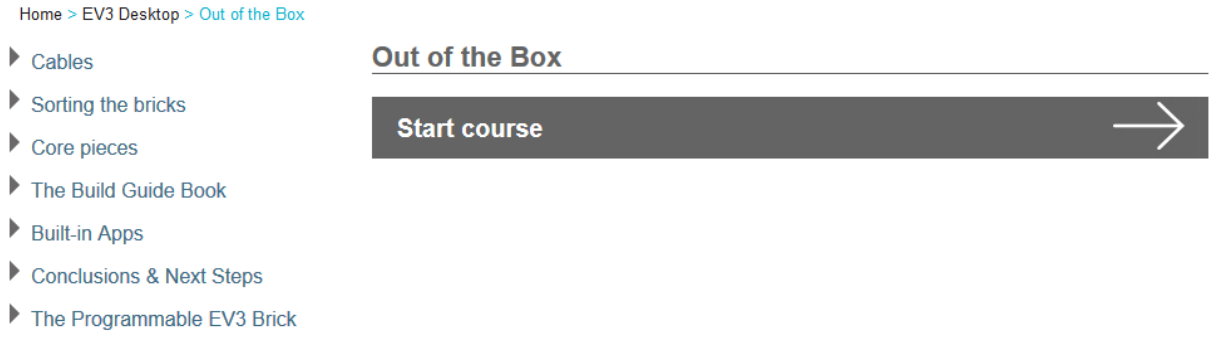


Help

[EV3 FAQ]

I. Getting Started - Out of the Box

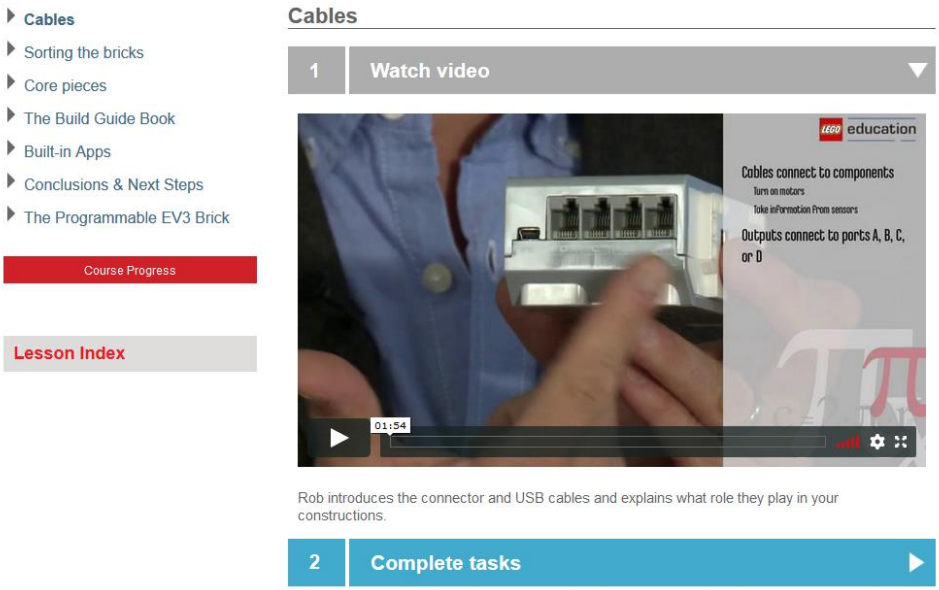
https://elearning.legoeducation.com/courses/out-of-the-box

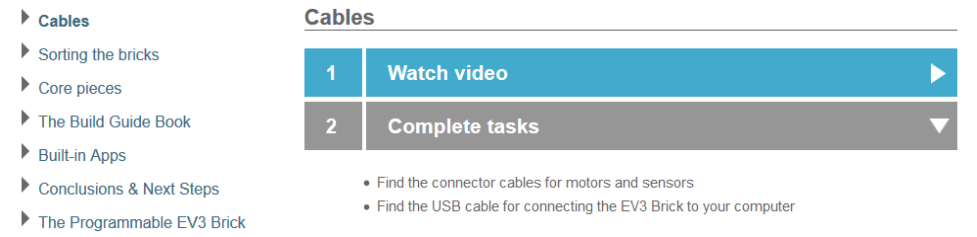


1. Cables
2. Sorting the bricks
3. Core pieces
4. The Build Guide Book

1. CABLES

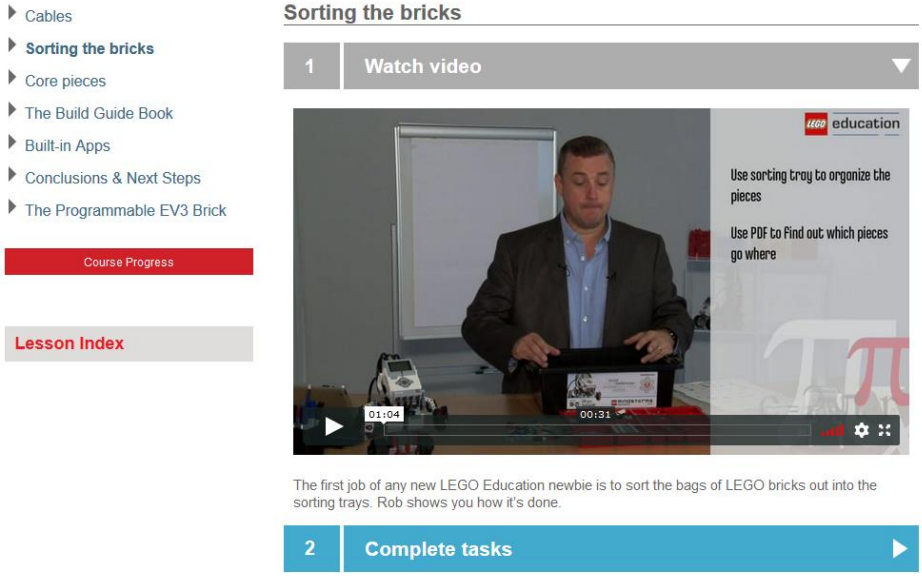
https://elearning.legoeducation.com/lessons/cables

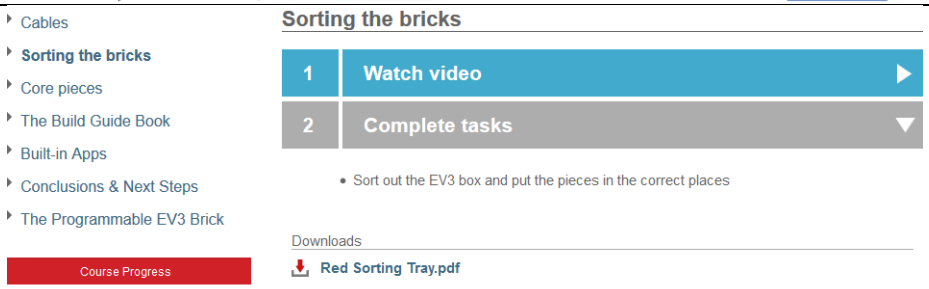




2. SORTING THE BRICKS

https://elearning.legoeducation.com/lessons/sorting-the-bricks

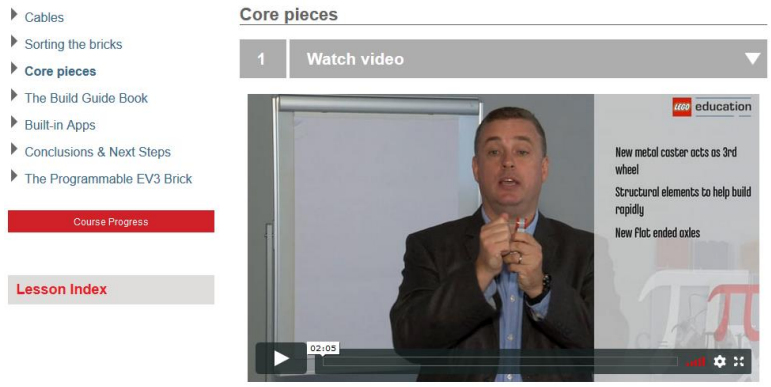


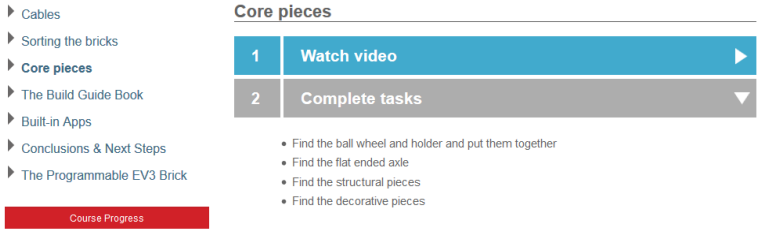


Red Sorting Tray.pdf
https://elearning.legoeducation.com/wp-content/uploads/2013/11/Module-1-red-sorting-tray.pdf

3. CORE PIECES

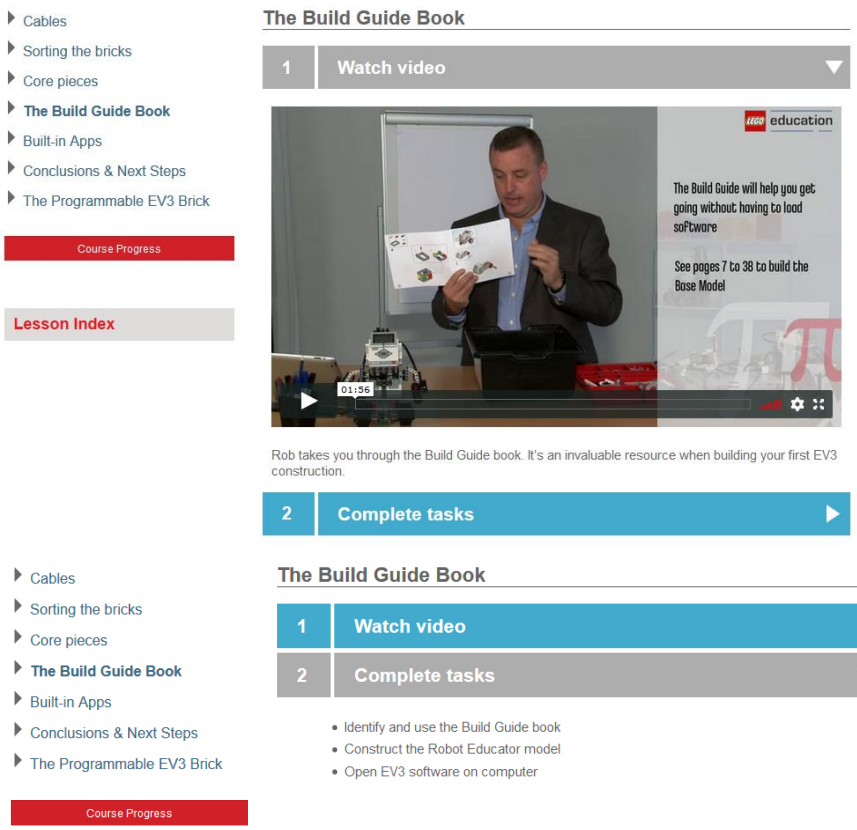
https://elearning.legoeducation.com/lessons/core-pieces





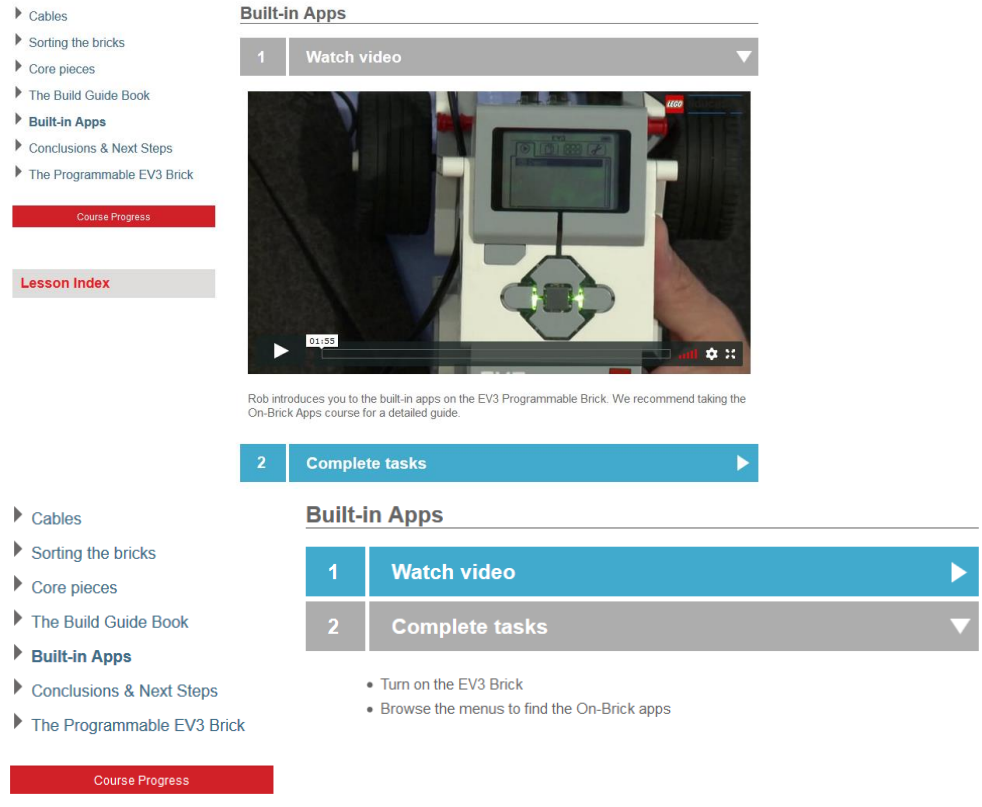
4. THE BUILD GUIDE BOOK

https://elearning.legoeducation.com/lessons/the-build-guide-book



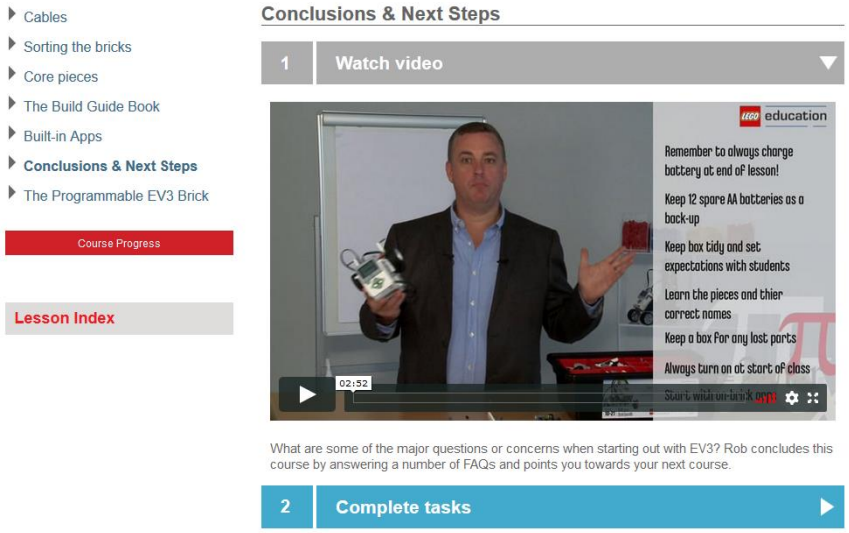
5. BUILT-IN APPS

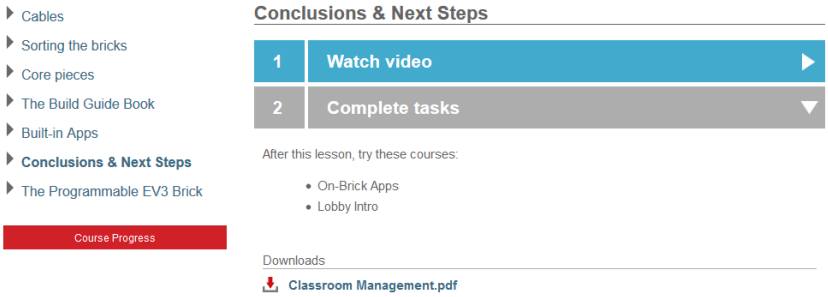
https://elearning.legoeducation.com/lessons/built-in-apps



6. CONCLUSIONS & NEXT STEPS

https://elearning.legoeducation.com/lessons/conclusions-next-steps



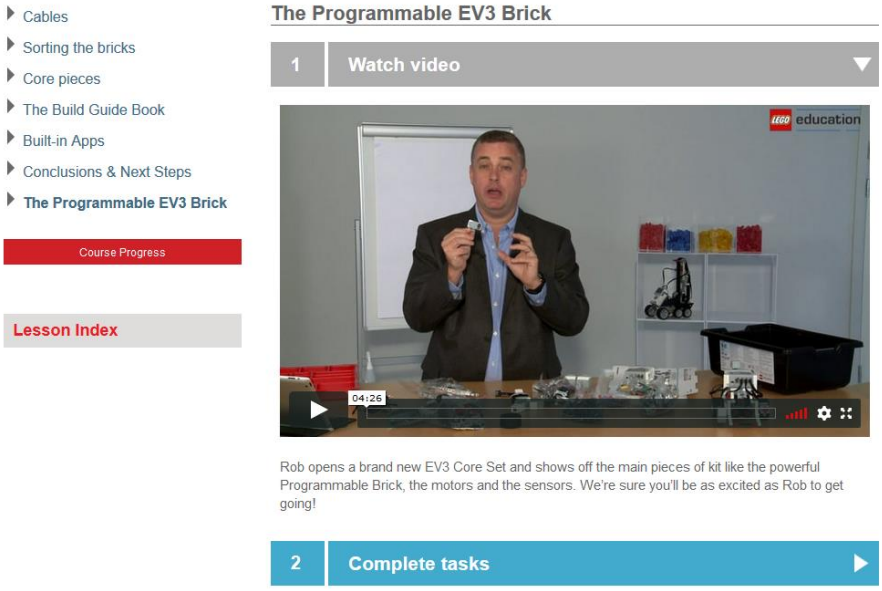


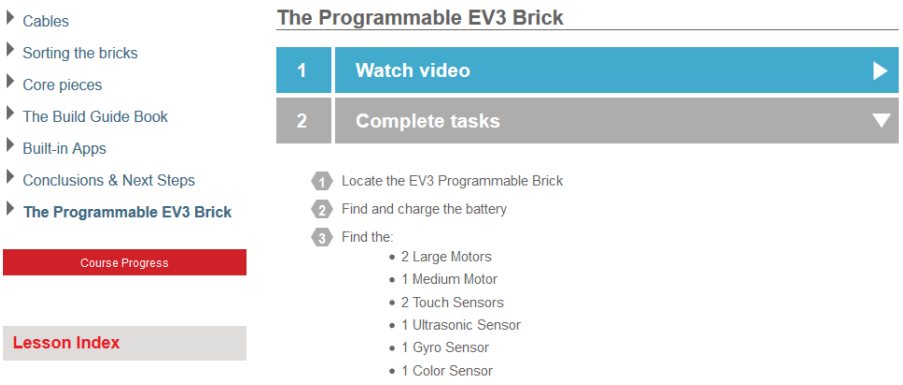
Classroom Management.pdf

https://elearning.legoeducation.com/wp-content/uploads/2013/11/Module-1-Classroom-Management.pdf

7. THE PROGRAMMABLE EV3 BRICK

https://elearning.legoeducation.com/lessons/the-programmable-ev3-brick

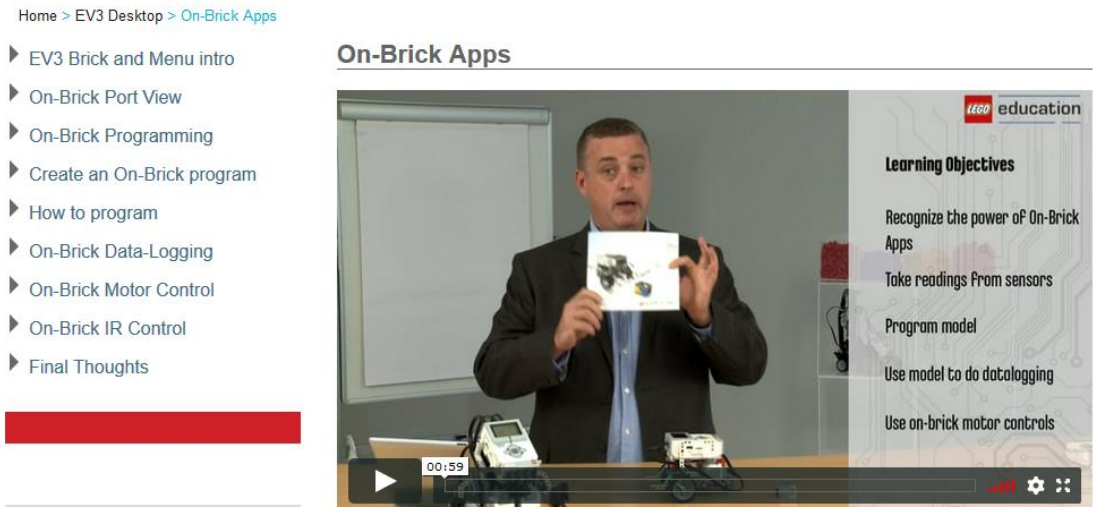




1. Locate the EV3 Programmable Brick
2. Find and charge the battery
3. Find the:
    - 2 Large Motors
    - 1 Medium Motor
    - 2 Touch Sensors
    - 1 Ultrasonic Sensor
    - 1 Gyro Sensor
    - 1 Color Sensor

II. Getting Started - On-Brick Apps

https://elearning.legoeducation.com/courses/on-brick-apps



EV3 Brick and Menu intro
On-Brick Port View
On-Brick Programming
Create an On-Brick program
How to program
On-Brick Data-Logging
On-Brick Motor Control
On-Brick IR Control
Final Thoughts

In this skills session, will guide you through the on-brick applications found on the programmable EV3 Brick. The beauty of these apps is you don't need a computer to program your robot!

Starts by taking you through the menus and how to navigate them. Discover how to use the Port View so you can get instant readings from the connected sensors.

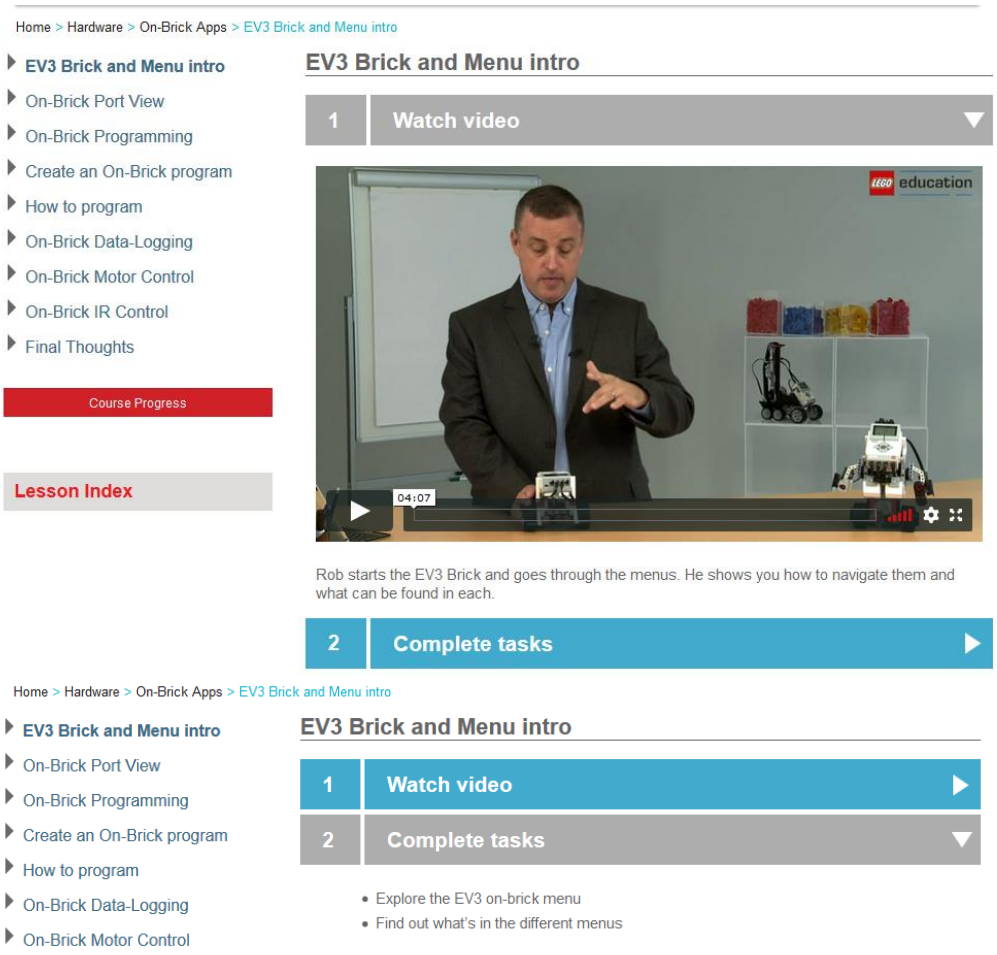
Find out how to program directly on the brick and then create your first on-brick program with a hands-on activity.

See how data logging makes it possible to capture live data or store them for later analysis and try it out on your own with the color sensor. Add motors and find out how to control them using the buttons on the EV3 Brick. Then, learn how use infrared control so you can control the EV3 robot remotely.

Finish off the course by hearing about questions that have come up during classroom-based workshops and learn about some of the considerations when working with the on-brick apps.

1. EV3 BRICK AND MENU INTRO

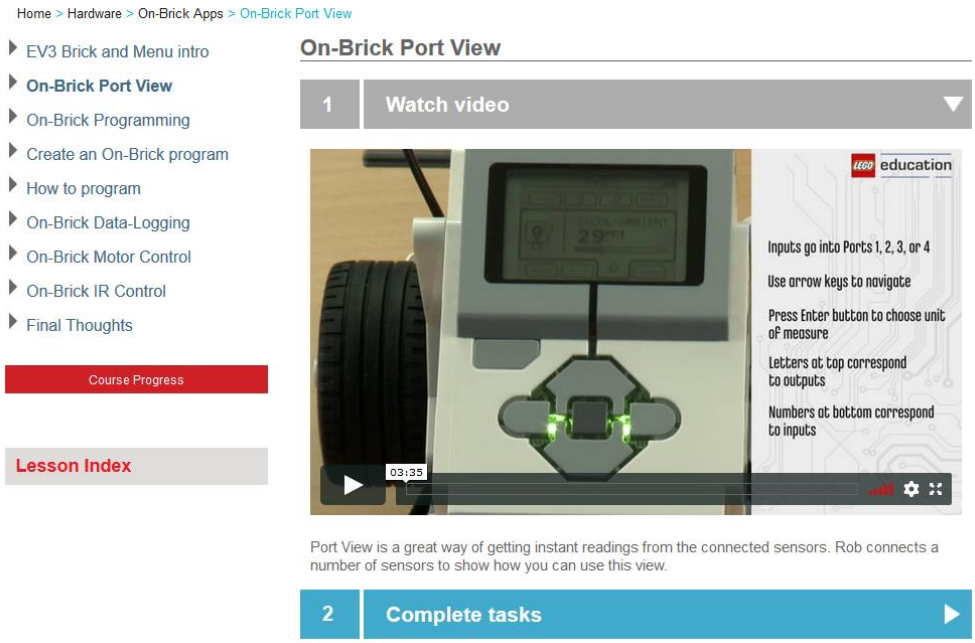
https://elearning.legoeducation.com/lessons/introducing-the-ev3-brick-menus



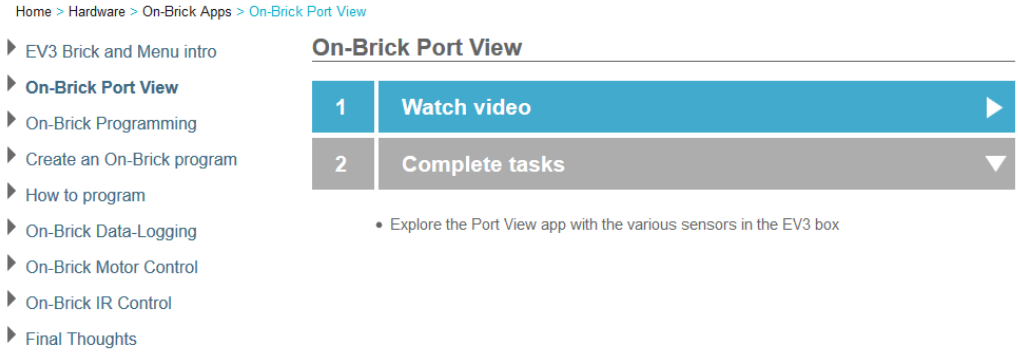
- Explore the EV3 on-brick menu
- Find out what's in the different menus

2. ON-BRICK PORT VIEW

https://elearning.legoeducation.com/lessons/on-brick-port-view



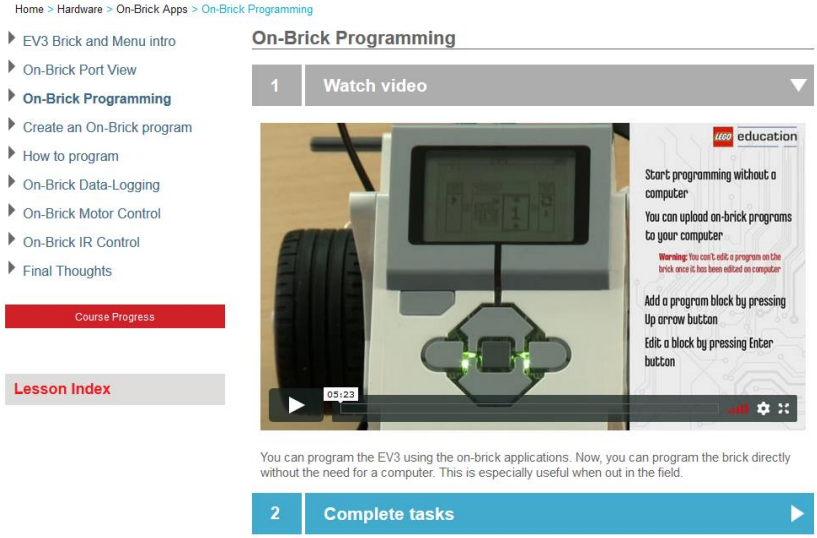
Port View is a great way of getting instant readings from the connected sensors. You connects a number of sensors to show how you can use this view.



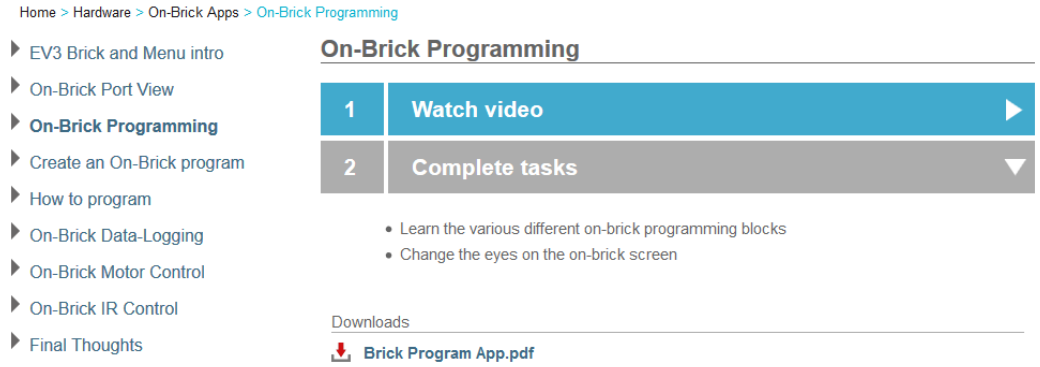
Explore the Port View app with the various sensors in the EV3 box

3. ON-BRICK PROGRAMMING

https://elearning.legoeducation.com/lessons/on-brick-programming



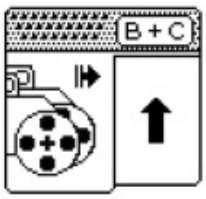
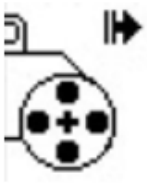
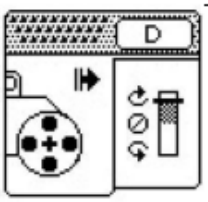
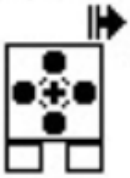
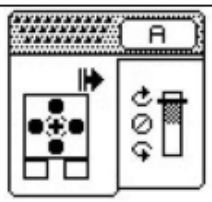
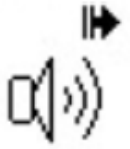
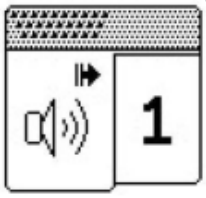
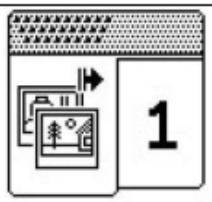
You can program the EV3 using the on-brick applications. Now, you can program the brick directly without the need for a computer. This is especially useful when out in the field.

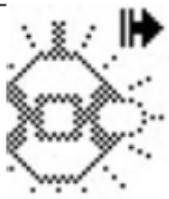
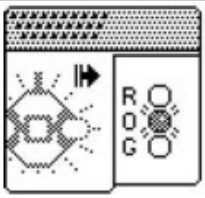
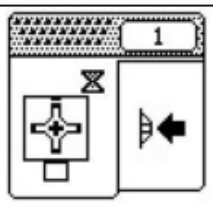
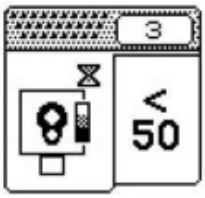
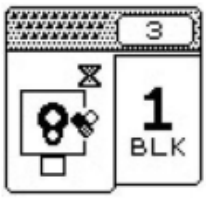
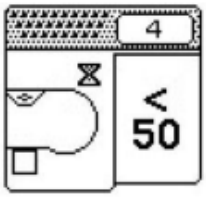
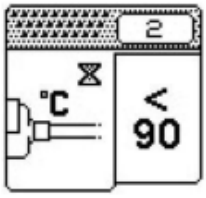


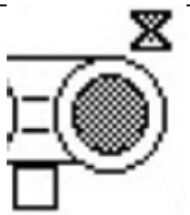
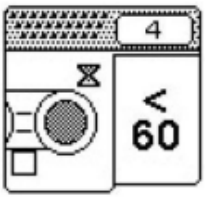
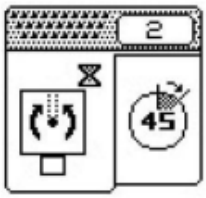
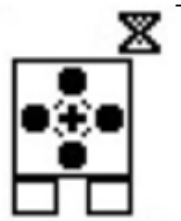
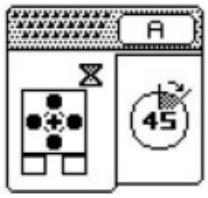
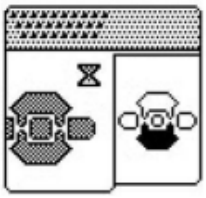
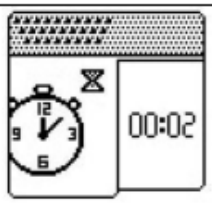
- Learn the various different on-brick programming blocks
- Change the eyes on the on-brick screen

Brick Program App.pdf

https://elearning.legoeducation.com/wp-content/uploads/2013/11/Module-2-Brick-Program-App.pdf

Block Name	Palette Icon	Programming Block
Loop	N/A	
Action Move Steering		
Action Large Motor		
Action Medium Motor		
Action Sound		
Action Image		

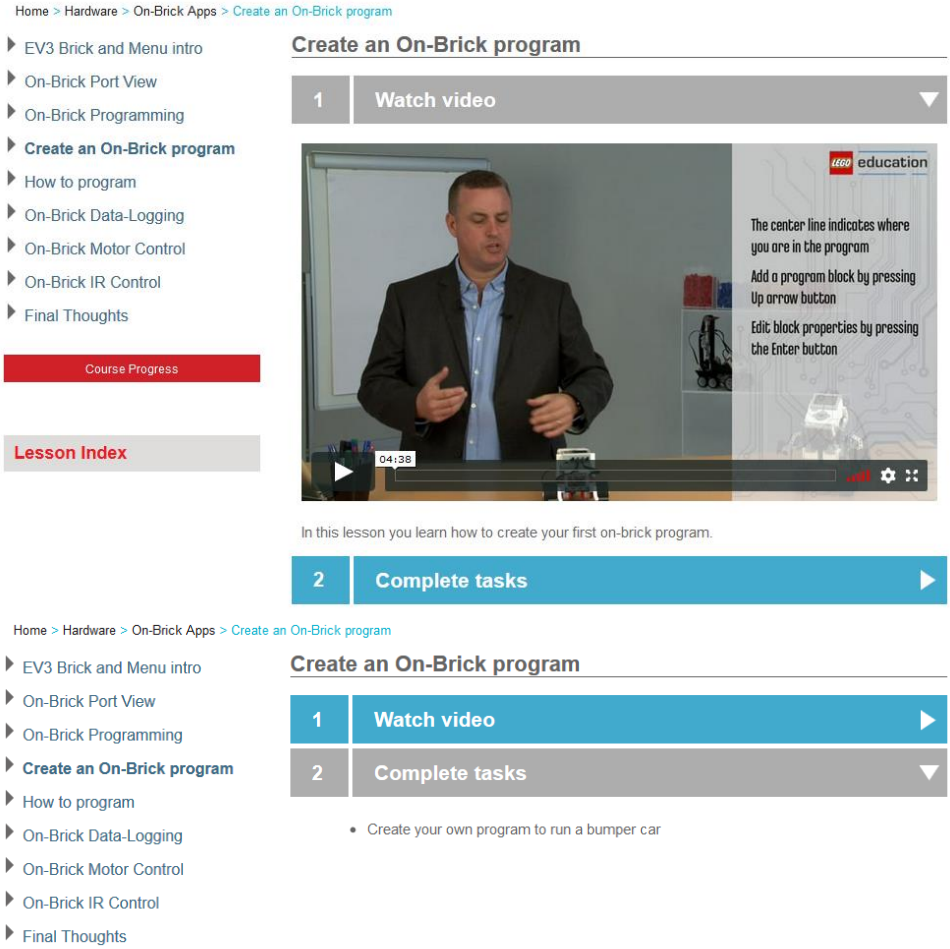
Action Button Light		
Wait Touch Sensor		
Wait Color Sensor Reflected Mode		
Wait Color Sensor Color Mode		
Wait IR Sensor Remote Mode		
Wait IR Sensor Proximity Mode		
Wait Temperature Sensor		

Wait Ultrasonic Sensor		
Wait Gyro Sensor		
Wait Medium Motor		
Wait Button Input		
Wait Time		

4. CREATE AN ON-BRICK PROGRAM

https://elearning.legoeducation.com/lessons/create-an-on-brick-program

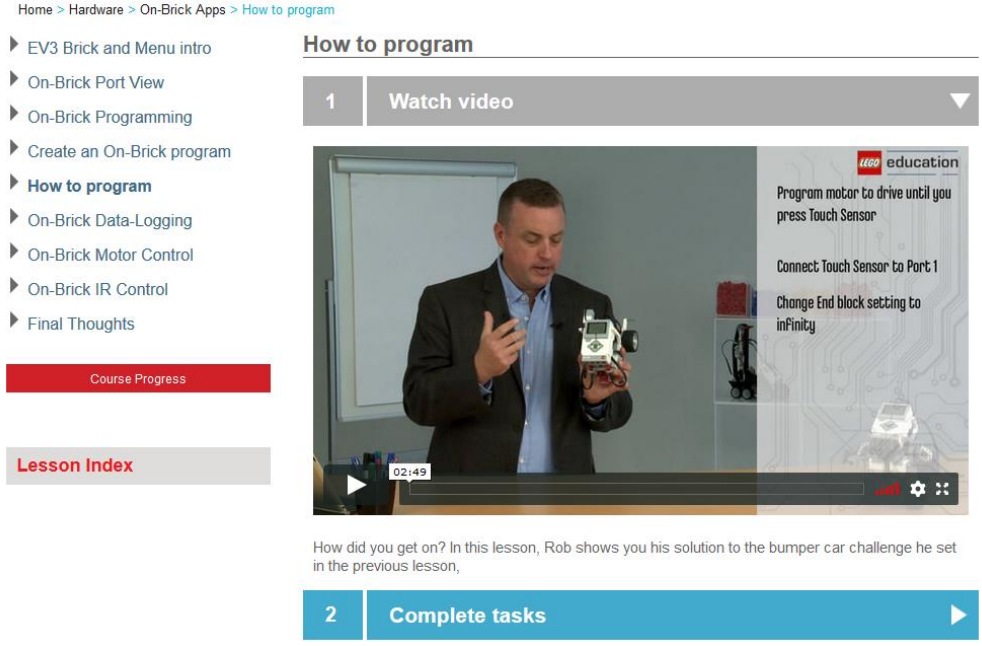
In this lesson you learn how to create your first on-brick program.



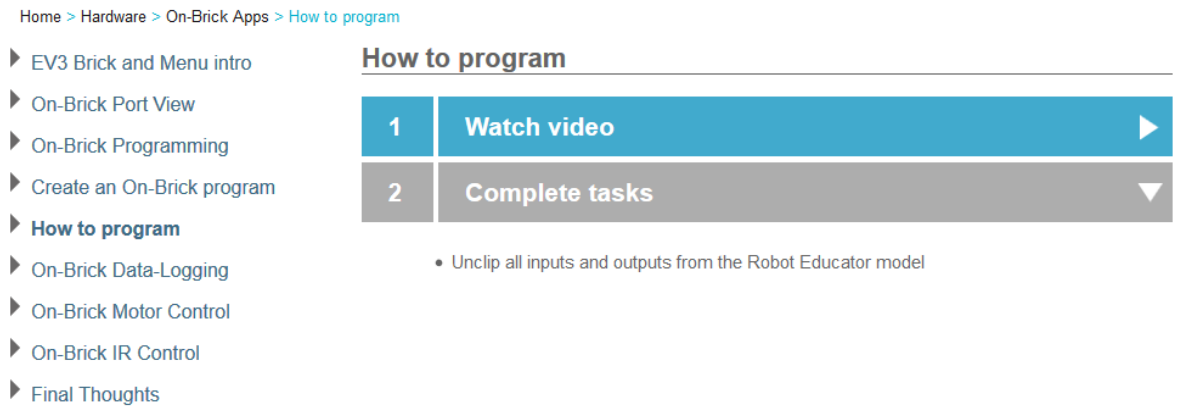
Create your own program to run a bumper car

5. HOW TO PROGRAM

https://elearning.legoeducation.com/lessons/how-to-program



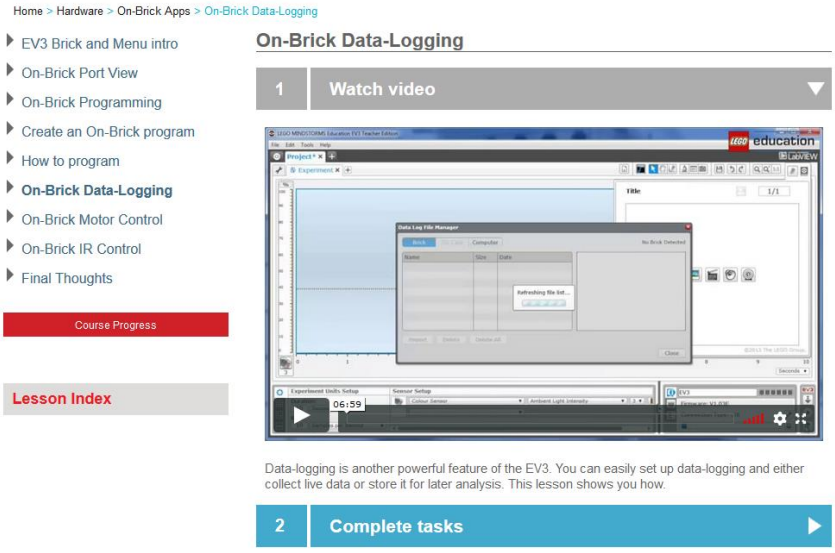
How did you get on? In this lesson, Rob shows you his solution to the bumper car challenge he set in the previous lesson



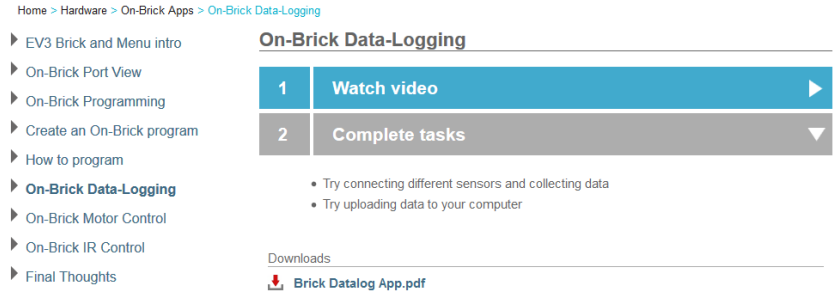
Unclip all inputs and outputs from the Robot Educator model

6. ON-BRICK DATA-LOGGING

https://elearning.legoeducation.com/lessons/on-brick-datalogging



Data-logging is another powerful feature of the EV3. You can easily set up data-logging and either collect live data or store it for later analysis. This lesson shows you how.



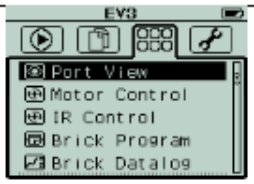
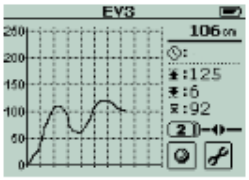
- Try connecting different sensors and collecting data
- Try uploading data to your computer

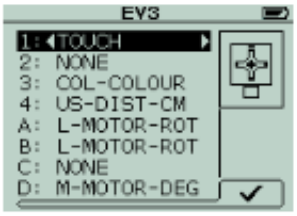
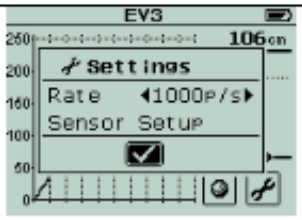
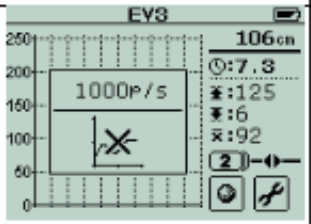
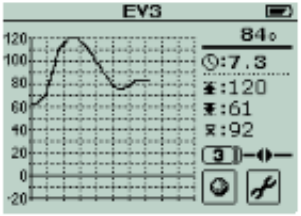
Brick Datalog App.pdf

https://elearning.legoeducation.com/wp-content/uploads/2013/11/Module-2-Brick-Datalog-App.pdf

Setting Up a Brick Programming Experiment

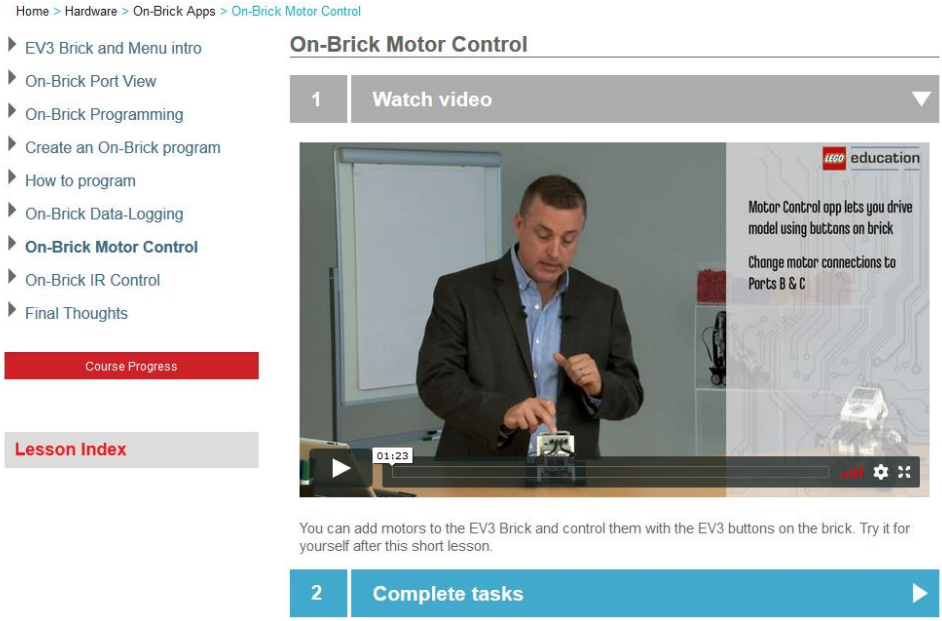
Ten Steps to Setting up a Great Brick Programming Experiment.

Step	EV3 Screen	Notes
1		Press the Enter key to turn on the EV3 Brick. It takes about 20–25 seconds for the EV3 Brick to turn on.
2		Then the Play menu appears. Users need to scroll across to the App menu.
3		Scroll past the File menu system.
4		When arriving at the App window, scroll down to the Brick Datalog App and press the Enter key.
5		Instantly the app launches a graph displaying the sensor/sensors connected. By clicking on either the left or right EV3 buttons, the Brick Datalog App will display the sensors that have been connected to the brick. You will notice on the clock/stopwatch that there is no time displayed. This indicates that the app is in Energy Meter mode and is not logging data.

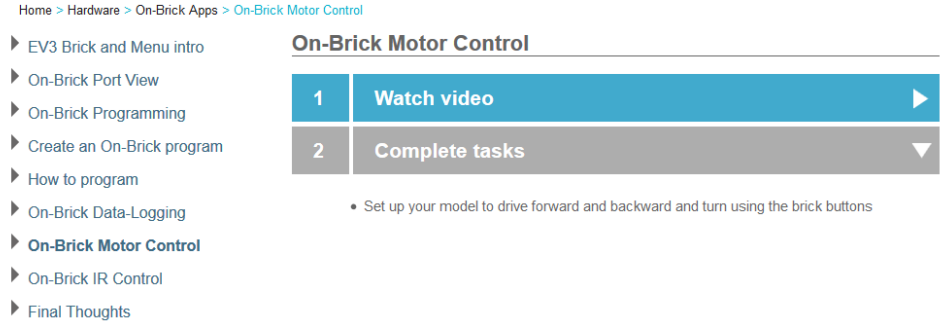
6		Many sensors have more than one unit of measure. By clicking on the Settings Tool (spanner), users can change the unit of measure. For example, as you can see here, the Color Sensor is set to record color, but it can be changed to log reflective and ambient light.
7		By clicking on the sample rate, users can change the number of samples taken per second.
8		Please note that once users try to log over 1,000 p/s, the data is recorded but cannot be displayed on-screen.
9		To start data logging, click on the sphere. The sphere will start flashing as the stopwatch/clock starts counting. On the EV3 Brick itself the status lights will flash green to indicate that it is collecting data. When you are ready to save the data, simply press the Enter key and you are prompted to save the data
10		Data collected can then be uploaded into the EV3 Software to analyze the results. Load the EV3 Software. Start an Experiment. Then click on the Upload button. The Data Log File Manager pop-up appears. Open the “BrkDL_SAVE” file and you will find the file name, for example, Rob. Import and analyze!!!

7. ON-BRICK MOTOR CONTROL

https://elearning.legoeducation.com/lessons/on-brick-motor-control



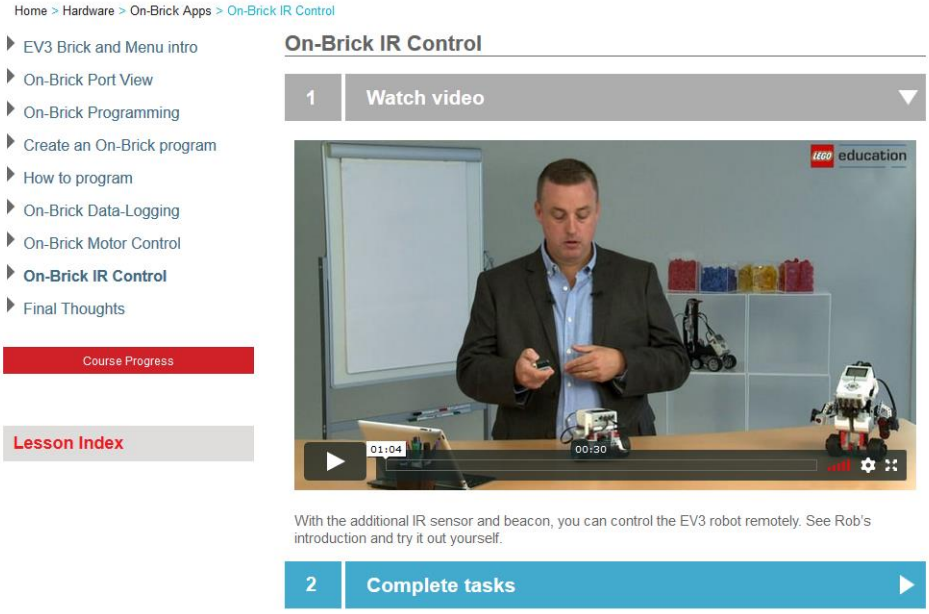
You can add motors to the EV3 Brick and control them with the EV3 buttons on the brick. Try it for yourself after this short lesson.



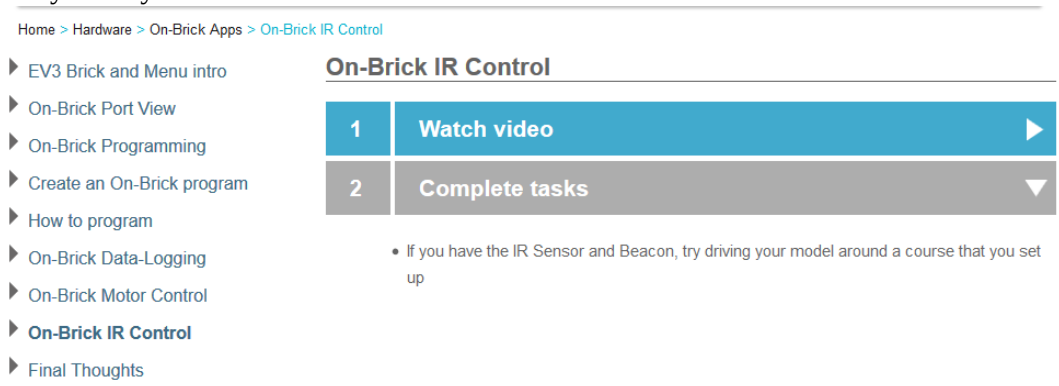
Set up your model to drive forward and backward and turn using the brick buttons

8. ON-BRICK IR CONTROL

https://elearning.legoeducation.com/lessons/on-brick-ir-control



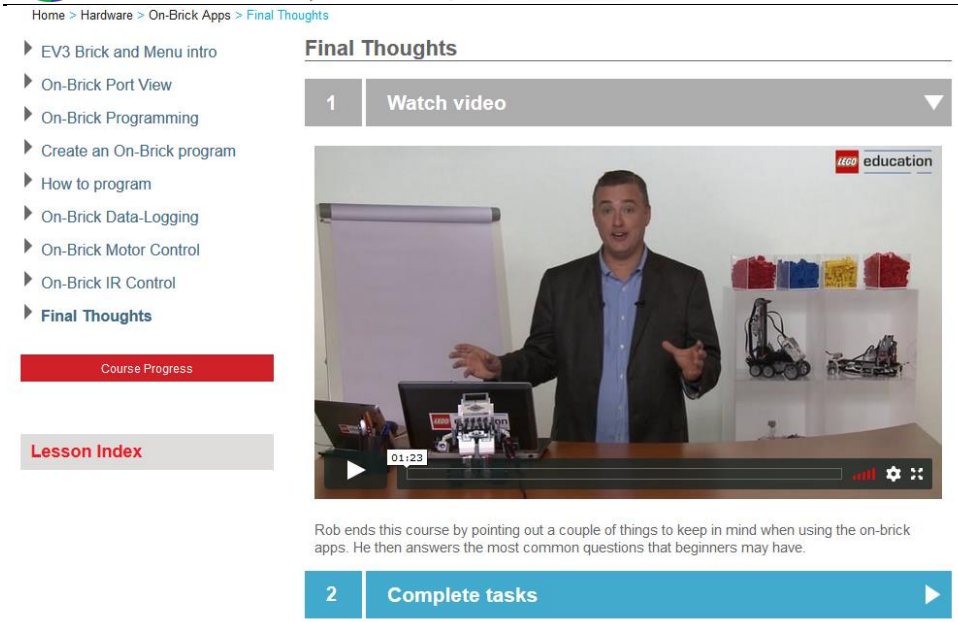
With the additional IR sensor and beacon, you can control the EV3 robot remotely. See introduction and try it out yourself.



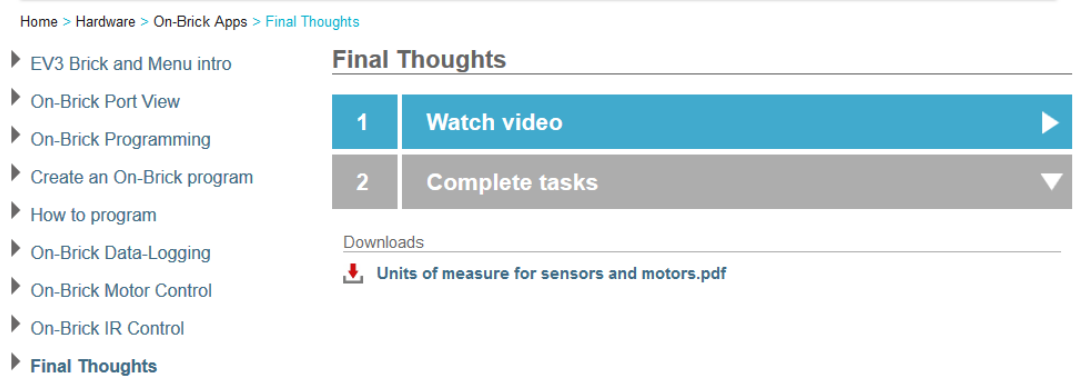
If you have the IR Sensor and Beacon, try driving your model around a course that you set up

9. CONCLUSIONS

https://elearning.legoeducation.com/lessons/final-thoughts



In the ends this course by pointing out a couple of things to keep in mind when using the on-brick apps. He then answers the most common questions that beginners may have.

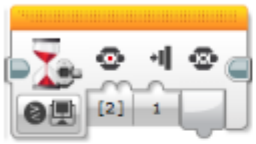


Units of measure for sensors and motors.pdf

https://elearning.legoeducation.com/wp-content/uploads/2013/11/Module-2-Units-of-Measure-for-Sensors-and-Motors.pdf

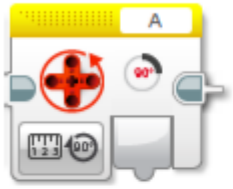
Units of Measure for Sensors and Motors

What are the units of measure for each sensor? Why do we use them?
This guide is used as a top-level overview. Much more detail can be found by pressing F1 in the software and launching the browser with the EV3 help files.

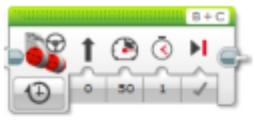
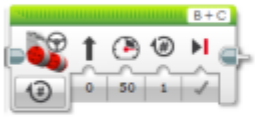
Sensors and Example Blocks	Units of Measure	Uses
Brick Buttons  	**Status** Pressed Released Bumped	*Used as an input similar to the Touch Sensor. Each button can be used as part of a program allowing an additional five Touch Sensors to be used. It's great for EV3 screen interaction.* *Pressed when the button is pressed, which continually counts items.* *Released when the button is let go.* *Bumped means the sensor is pressed and released, recording just one action, unlike when it's continuously pressed. It's great for an entry system, like a car park, where a car entering needs to be recorded.*

Color Sensor  	Color Reflected Light Intensity Ambient Light Intensity	*Color is used to recognize the seven LEGO colors (black, blue, green, yellow, red, white, brown, and no color).* *Reflected light intensity is used to obtain a value between 0–100 percent of an object. Red light is reflected back to the sensor providing the readings. This is great for things like line-following robots.* *Ambient light intensity is used to measure the natural light levels in a location. For example, the program recognizes a change from day to night.*
Gyro Sensor  	Angle Rate	*Angle is used primarily for recording the degree in which the robot has turned. When the robot is driving slowly, this is a great way to achieve accurate turns.* *When the sensor is turned in the direction of the arrows, the sensor can record the rate of rotation in degrees per second. This is great for keeping a Segway® robot from falling over.*

Infrared Sensor  	Proximity Beacon Heading Beacon Proximity Remote	*In IR Sensor Proximity mode, the Infrared Sensor sends out an infrared signal, and it can detect the reflection of this signal from an object in front of the sensor. The strength of the reflected signal can be used to estimate the proximity of (distance to) the object. You could use the IS Sensor Proximity mode, for example, to detect when your robot gets close to a wall.* *In Beacon Mode, the Infrared Sensor can detect the approximate position of the Remote Infrared Beacon (IR Beacon) in front of the sensor. The sensor can give you the Beacon's Proximity (the relative distance from the sensor) and its Heading (the angle in the direction the sensor is pointing). You could use the Beacon Mode, for example, to make your robot seek out and drive toward the IR Beacon.* *In Compare Remote mode, the Infrared Sensor can detect which button on the Remote Infrared Beacon (IR Beacon) is pressed. You can also detect when certain combinations of two buttons are pressed at the same time. You can use the Compare Remote mode, for example, to make a remote control for your robot.*

Motor Rotation   	Degrees Rotations Current Power	*Degrees are used for fine motor control and measurement. 360 degrees makes up one rotation.* *Rotation is the standard unit of measurement for most users when programming their robot to move around the classroom. Decimals can also be used when using rotations.* *Current Power can be used to monitor the current power of the motor. Plus it can be used as a trigger to stop the motor, for example, when the motor power drops below 50 percent.*
Temperature Sensor   	Celsius Fahrenheit	*Celsius is the measurement widely used in Europe.* *Fahrenheit is the measurement used in the USA.*

Timer  	Time Indicator	*EV3 Bricks have eight internal timers that can be used independently in a program. The timer is measured in seconds.*
Touch Sensor  	**Status** Pressed Released Bumped	*Pressed when the button is pressed, which continually counts items.* *Released when the button is let go.* *Bumped means the sensor is pressed and released, recording just one action, unlike when it's continuously pressed. It's great for an entry system, like a car park, where a car entering needs to be recorded.*
Ultrasonic Sensor  	Distance Centimeters Distance Inches Presence/Listen	*Distance is when the Ultrasonic Sensor detects objects in front of the sensor. This is done by sending out waves and measuring how long the reflected waves take to return. Depending on the selection, centimeters or inches are recorded.* *In Ultrasonic Listen Mode the Ultrasonic Sensor can be set to detect other Ultrasonic Sensors being used by other EV3 Bricks.*

Energy Meter  	In Voltage In Current In Wattage Out Voltage Out Current Out Wattage Joule	*The Energy Meter Block can be set up to monitor the different energy units of measure both in and out of the meter unit. Up to seven different values can be recorded, as shown opposite.*
NXT Sound Sensor  	dB dBa	*The sound level, scaled to a percentage.* *The sound level, adjusted to human ear sensitivity, and then scaled to a percentage.*
Motor Outputs   	Seconds Rotations Degrees	*Driving motors by seconds is the easiest way for students to start a program, but it is the least accurate method, because batteries are inconsistent. It is powerful if motors might stall, because then they can be reset.* *This is a simple way of moving the robot. One rotation will make the robot drive about 17.5 cm.* *For precise driving or measurements, degrees is by far the most accurate way of controlling a robot. One rotation = 360 degrees.*

Part 2. 3D Printing

FAB LAB PALERMO

3D Printing at school (grades 7-12) *november 2019 version*

THINK IT, MAKE IT

The following slides are a tool for a course that wants to provide the basics to start with 3D printing at school, with the suggestion to practice constantly and to contact a local Fablab for further information and insights.

Summary

- some "additive manufacturing" technologies
- what can be done with 3D FDM printing (fused deosition modeling)
- how a 3D printer is made and how it works - materials
- from the 3D model to the printing: g-code and SLICING
- settings of a slicing software - Ultimaker CURA
- the 3d printer at work: suggestions for use and maintenance
- 3D files: format, finding a model, modification or creation
- create an object: suggestions for 3D modeling
- find an object: suggestions for online research
- educational models: some examples of printable 3D STEAM models

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ADDITIVE MANUFACTURING

CAD → **Printing instructions** → **G-Code** → **3D Printing**

Computer Aided Design:
The 3D digital model is created by the use of a 3D modeling software

The model is translated into instructions concerning movements and temperature

SLA
DLP
LCD
FDM
SLS
Etc...

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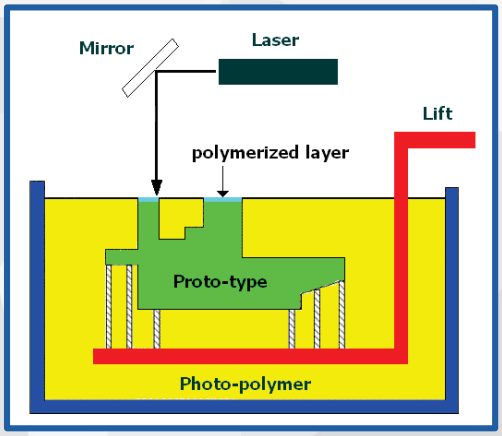
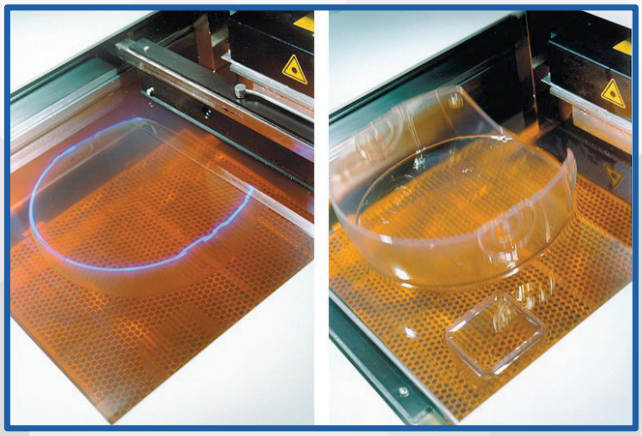
ADDITIVE MANUFACTURING

SLA - Stereolithography

Laser Stereolithography: a laser beam is guided to hit a resin that becomes solid due to photopolymerization, creating the 3D model, layer by layer.





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ADDITIVE MANUFACTURING

SLA - Stereolitografia

Laser Stereolithography: a laser beam is guided to hit a resin that becomes solid due to photopolymerization, creating the 3D model, layer by layer.

Cost of a "desktop" SLA 3D printer: about € 3.000
A cleaning system with suitable detergents and an additional UV lamp is required for complete polymerization.
A fume extraction system or a well-ventilated room is recommended.

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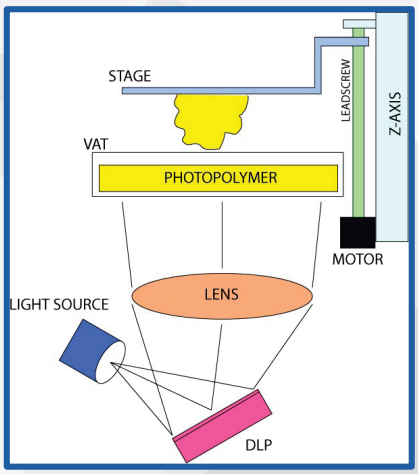
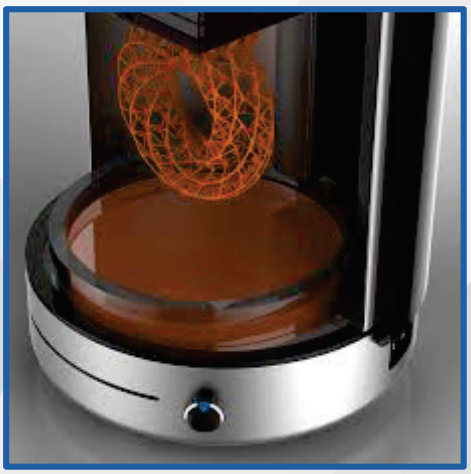
ADDITIVE MANUFACTURING

DLP – digital light processing

a series of projected light images hits a resin that becomes solid due to photopolymerization, creating the 3D model, layer by layer.





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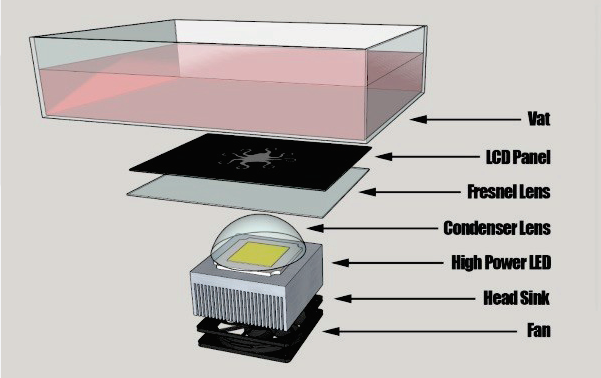
ADDITIVE MANUFACTURING

LCD

LCD: the light from a LED having a certain wavelength is masked by an LCD panel; this panel creates the images to hit a resin that become solid due to photopolymerization



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ADDITIVE MANUFACTURING

LCD

LCD: the light from a LED having a certain wavelength is masked by an LCD panel; this panel creates the images to hit a resin that become solid due to photopolymerization

Cost of a "desktop" LCD 3D printer: about € 500
A cleaning system with suitable detergents and an additional UV lamp is required for complete polymerization.

A fume extraction system or a well-ventilated room is recommended.

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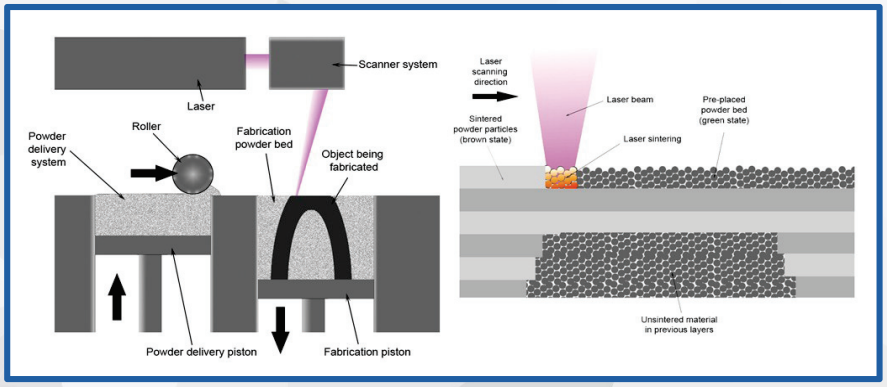
ADDITIVE MANUFACTURING

SLS – Selective Laser Sintering

A laser beam is guided to hit thin layers of polymer powder creating, by local melting, layer by layer, the 3d model.



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ADDITIVE MANUFACTURING

SLS – Selective Laser Sintering

A laser beam is guided to hit thin layers of polymer powder creating, by local melting, layer by layer, the 3d model.

Cost of a "desktop" SLS 3D printer: > €10.000

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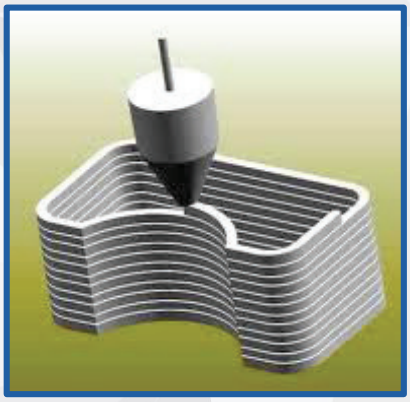
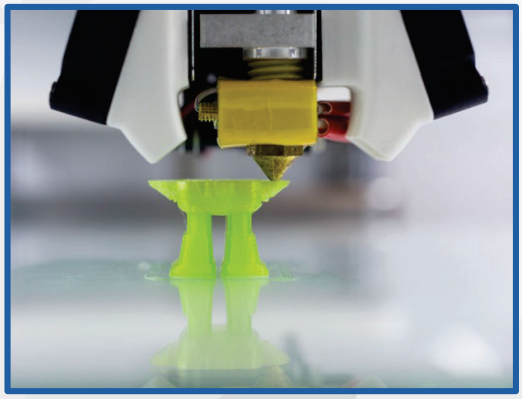
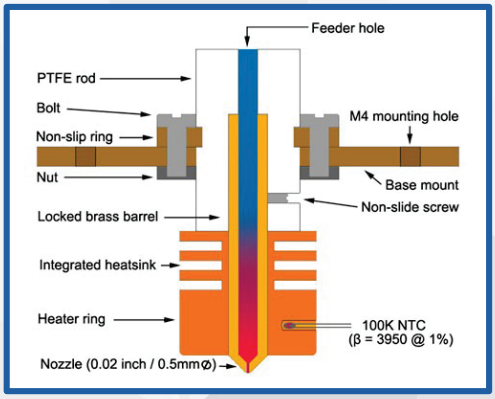
ADDITIVE MANUFACTURING

FDM – Fused deposition modeling

A thermoplastic polymer is extruded melted by a nozzle which, by moving, creates a layer of the 3D model







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ADDITIVE MANUFACTURING

FDM – Fused deposition modeling

A thermoplastic polymer is extruded melted by a nozzle which, by moving, creates a layer of the 3D model

Cost of a FDM 3D printer: starting from €250
No need for further processing.

A fume extraction system or a well-ventilated room is recommended.

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ADDITIVE MANUFACTURING

FDM VS LCD

Standard printing volume:
250x250x250mm

Printable smaller detail:
about 1mm

Suitable for the school environment

Standard printing volume:
100x100x150mm

Printable smaller detail:
about 0,05mm

Less suitable for the school environment

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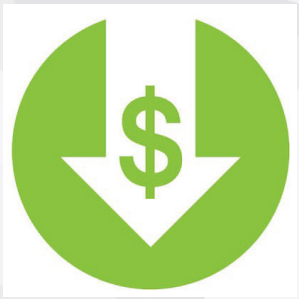
Pros and cons of filament 3D printing

Low equipment costs
Low material costs
Easy to handle materials

Less precision than other AM techniques
Limited material range
Limited size



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What can be done with FDM 3D printing

Fashion and accessories

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What can be done with FDM 3D printing

Event Gadgets

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What can be done with FDM 3D printing

Commercial Gadgets

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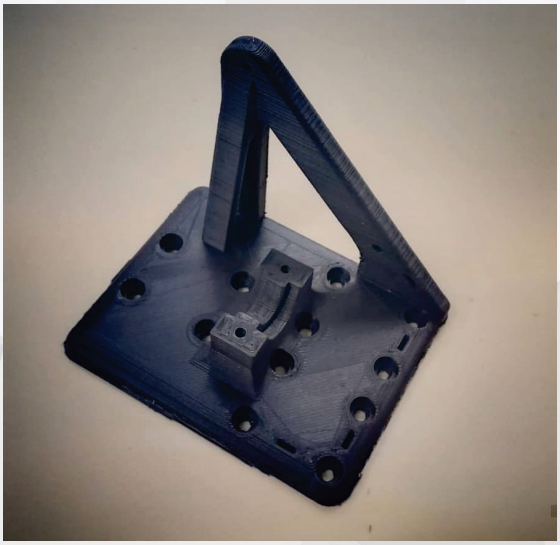
What can be done with FDM 3D printing

Prototypes for design and industry



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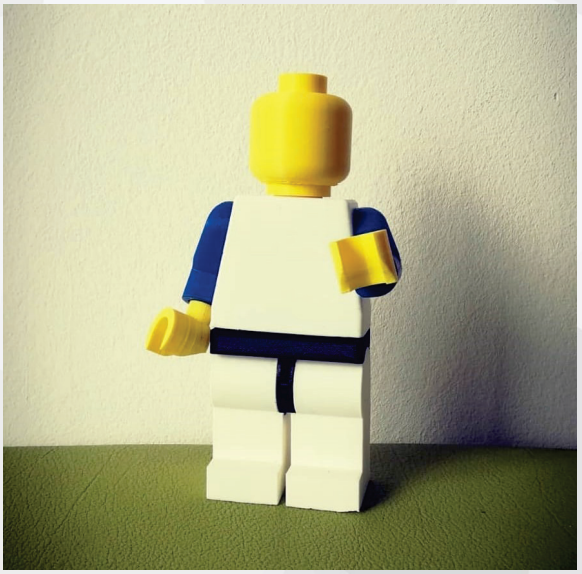
What can be done with FDM 3D printing

Artistic objects and action figures



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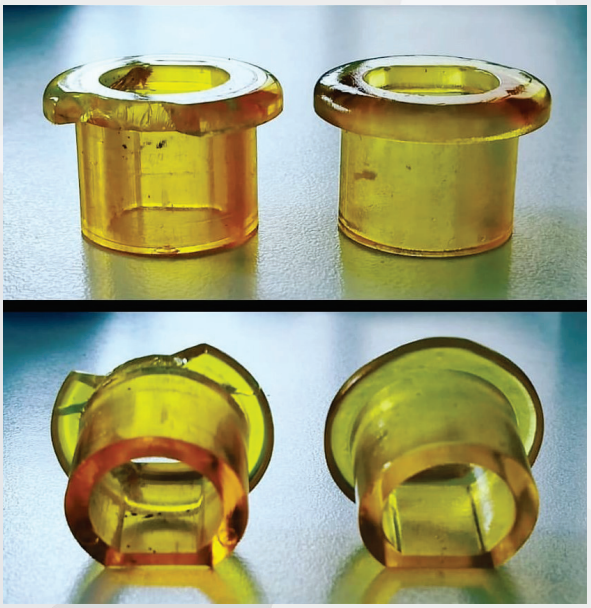
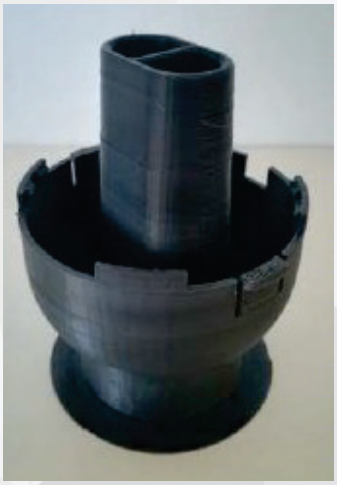
What can be done with FDM 3D printing

Reconstructions of broken parts





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What can be done with FDM 3D printing

Reconstructions of broken parts

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What can be done with FDM 3D printing

Reconstruction of museum exhibits

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What can be done with FDM 3D printing

Reconstruction of museum exhibits

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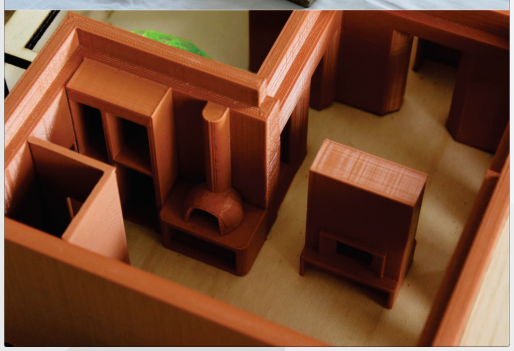
What can be done with FDM 3D printing

Architectural models



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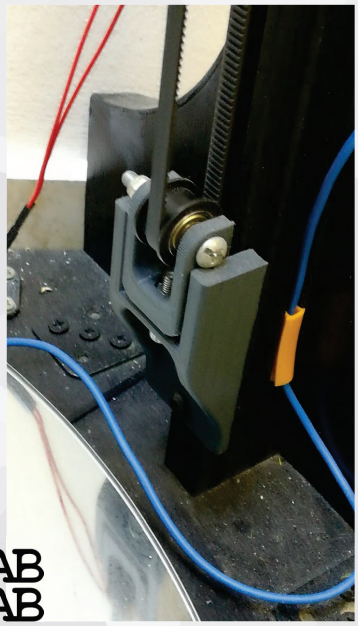
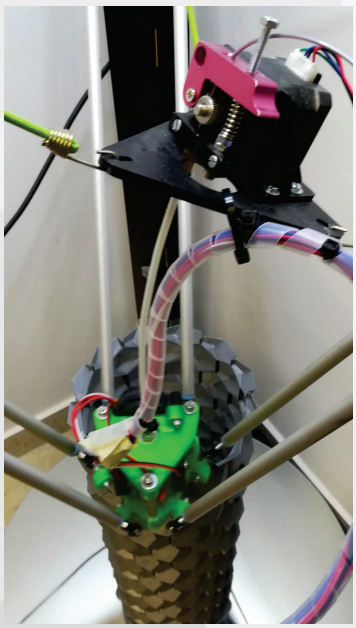
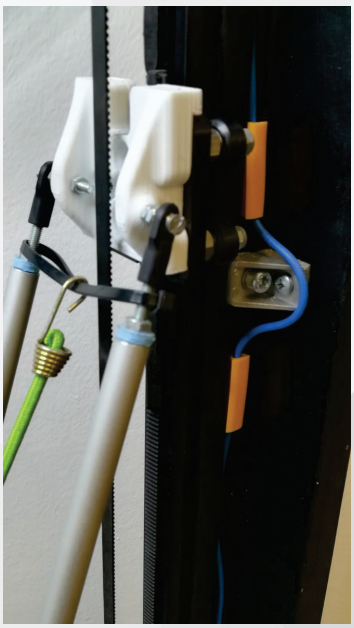
What can be done with FDM 3D printing

Mechanical upgrades for printers and more







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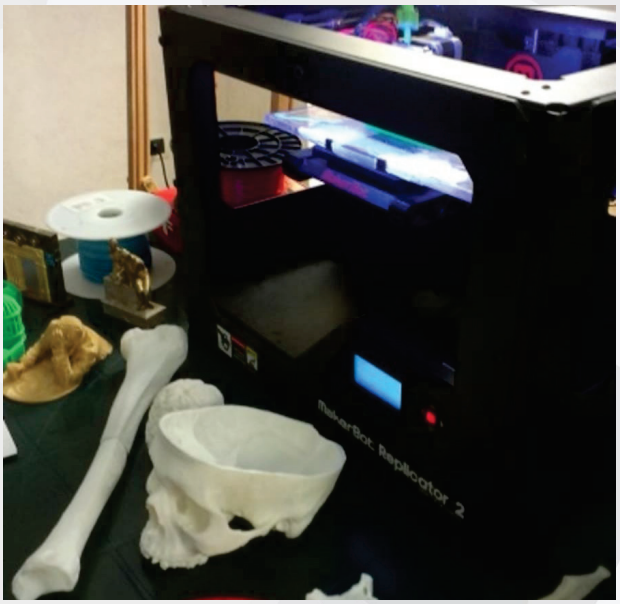
What can be done with FDM 3D printing

Models for pre-surgical diagnosis and simulations



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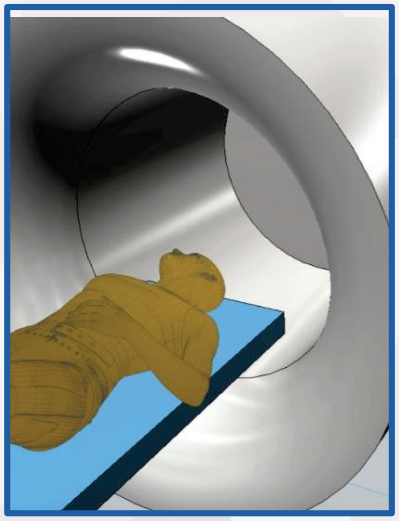
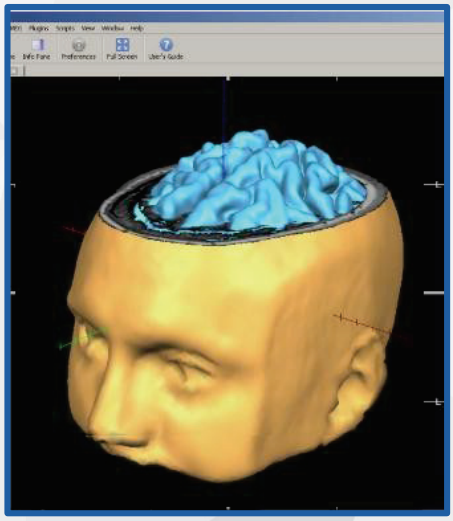
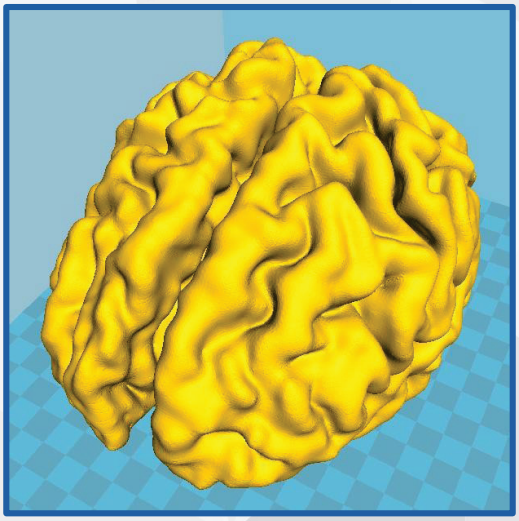
What can be done with FDM 3D printing

Models for pre-surgical diagnosis and simulations







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What can be done with FDM 3D printing

Master models

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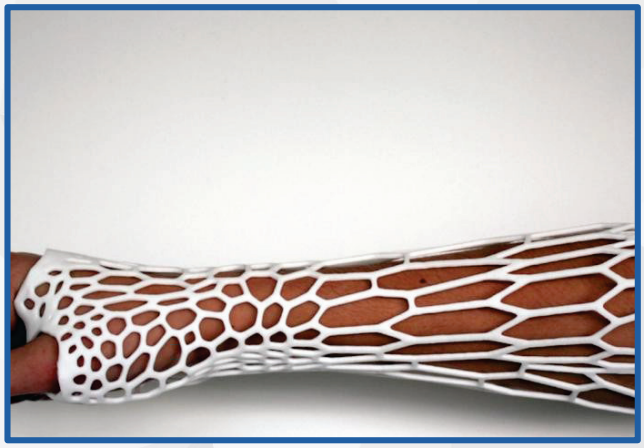
What can be done with FDM 3D printing

Orthopedic braces and prosthetics



E-nable: http://enablingthefuture.org/

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What can be done with FDM 3D printing

Educational three-dimensional models

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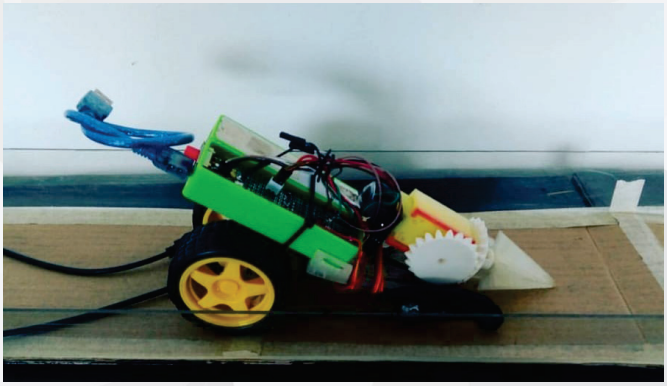
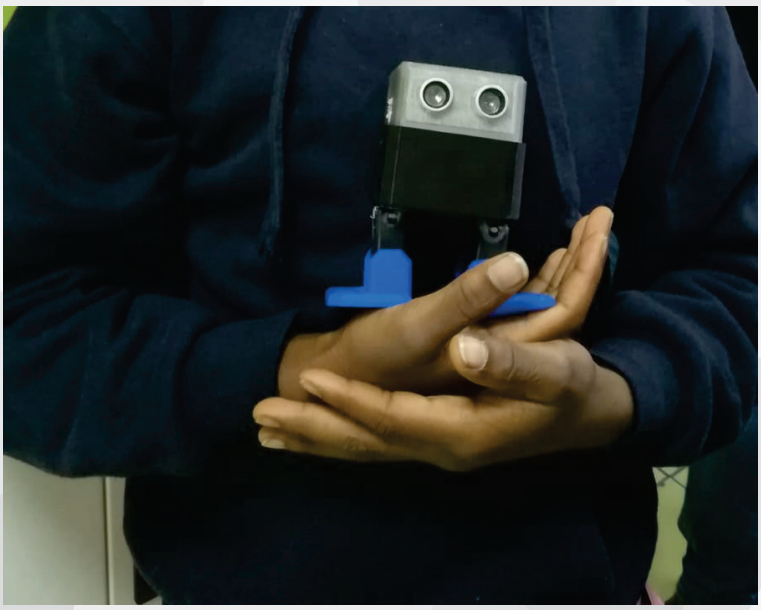
What can be done with FDM 3D printing

Educational three-dimensional models





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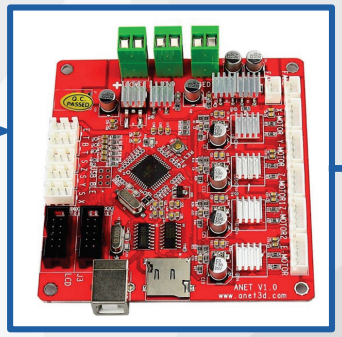
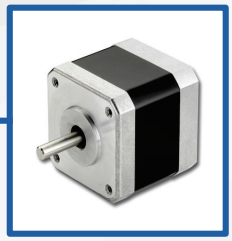
How an FDM 3D printer is made

The electronic board, reading the file "G-code", manages the movement of the motors, the resistances and the temperature sensors. The motors are "stepper motors", which can even rotate of a fractions of a degree

G-code

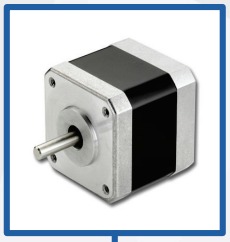


X

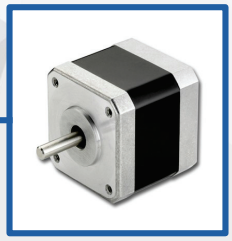


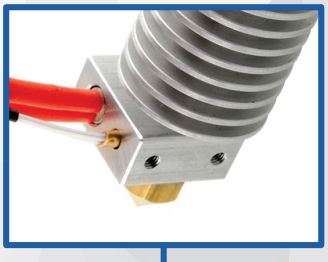
Y

Z



Estrusore





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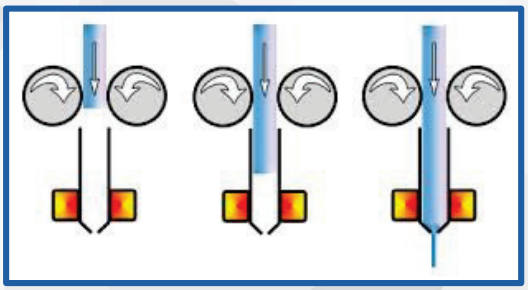
How an FDM 3D printer is made

A spring mechanism holds the filament tight between two pulleys, one of which is knurled and connected to a stepper motor, which pushes the filament towards the "hot end" of the extruder, where the filament melts and comes out extruded from the hole of the nozzle, usually with a diameter of 0.4mm.



Estrusione

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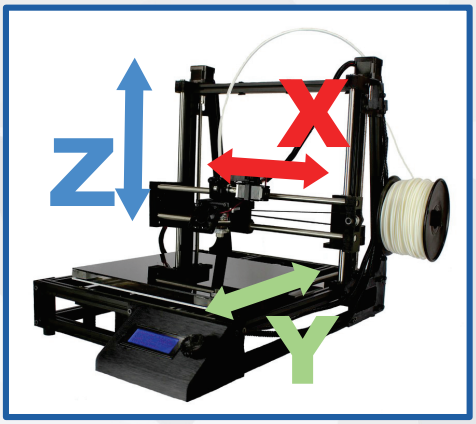
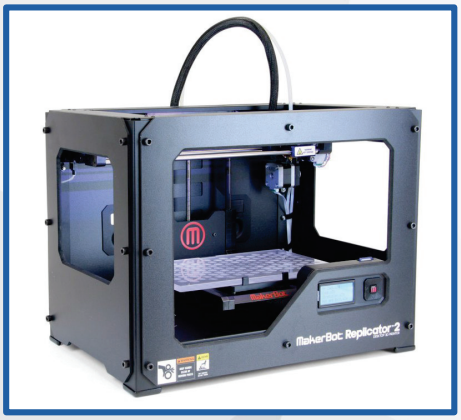
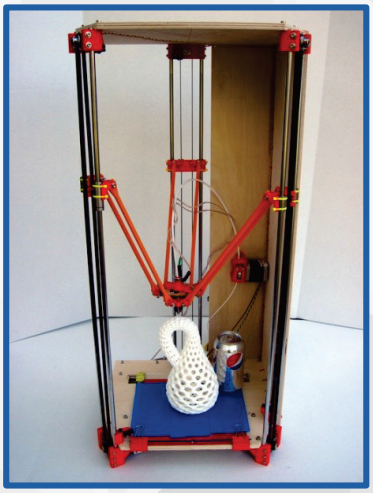
How an FDM 3D printer is made







Different layouts (Mechanical arrangements)

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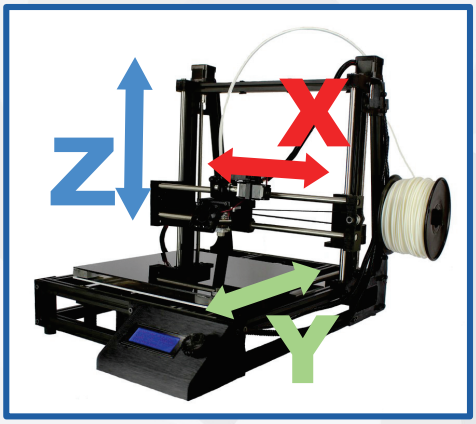
How an FDM 3D printer is made



Cartesian-XZ-head, ("Prusa" style)

- The print bed moves along "Y"
- The printer frame is usually "open"
- Cheap layout
- Not recommended for materials such as ABS

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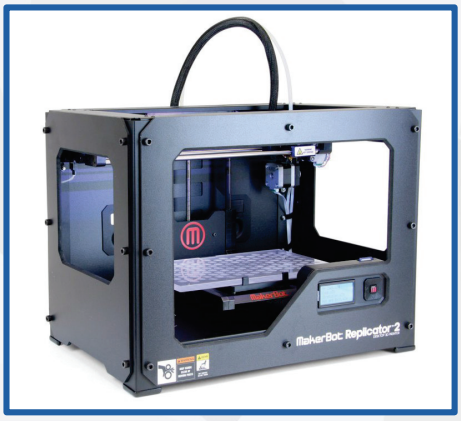
Come è fatta una stampante 3D FDM



Cartesian-XY-head

- The print bed moves along "Z"
- The printer frame is usually "closed"
- Less cheap layout
- Recommended for materials such as ABS

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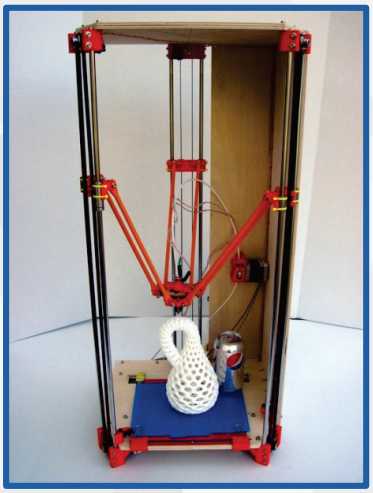
Come è fatta una stampante 3D FDM

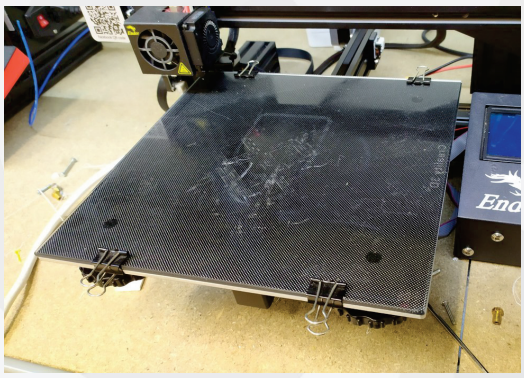


Delta

- The print bed does not move
- The printer frame is usually "closed"
- Less economical layout
- If well constructed, it allows fast and precise printing
- Recommended for materials such as ABS

More layouts:
https://reprap.org/wiki/Category:Mechanical_arrangement

Come è fatta una stampante 3D FDM



The "printing bed"

Regardless of the layout, even the most economical printers are now equipped with a heated printing bed.

This reduces the risk of thermal shock and significantly increases the adhesion of the print piece to the bed, which is an aspect that often throws those who print into crisis.
The printing beds can reach up to 80-90 ° C.
The temperature varies with the material to be printed.

The most used materials for FDM 3D Printing

PLA (polylactic acid)
Printing temp.: 180°-210°
Bed temp.: 50°-60°
Costs: 20-30 €/kg
Origin: renewable resources
Shrinking: negligible
Easy to sand down: no
Mechanical strength: good
Ease of printing: easy (even on a cold bed)

More materials:
PET e PET-G, PLA FLEX, PVA, Laywood, CarbonFill, PC, PMMA, HIPS etc.

All thermoplastic polymers!

ABS
Printing temp.: 220°-250°
Bed temp.: 70°-90°
Costs: 20-30 €/kg
Origin: petrochemical
Shrinking: NOT negligible
Easy to sand down: yes
Mechanical strength: good
Ease of printing: tricky – heated bed

Nylon
Printing temp.: 220°-260°
Bed temp.: 70°-90°
Costs: 20-30 €/kg
Origins: petrochemical
Shrinking: NOT negligible
Easy to sand down: medium ease
Resistenza: very good
Ease of printing: tricky – heated bed

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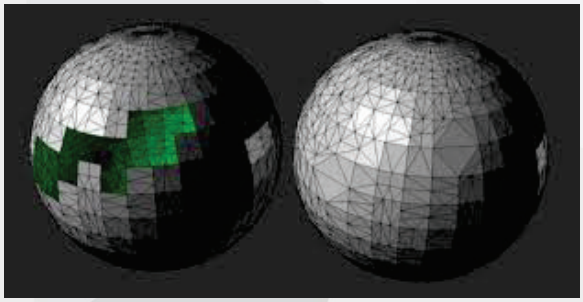
3D files

Preferable formats: STL and OBJ
File type: closed mesh (Watertight)
Where to find online: Thingiverse, Myminifactory, 3Dcontent etc.
3D scanning/fotogrammety/MRI scan
Modification: Meshmixer, Blender etc
Creation: Tinkercad, Blender, Fusion 360, Solidworks, Rhinoceros etc. etc. etc…



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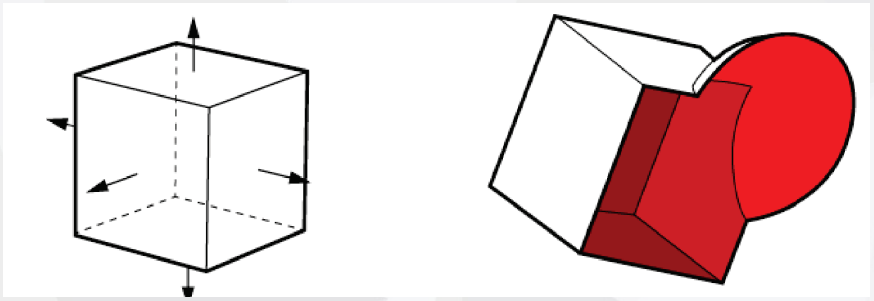
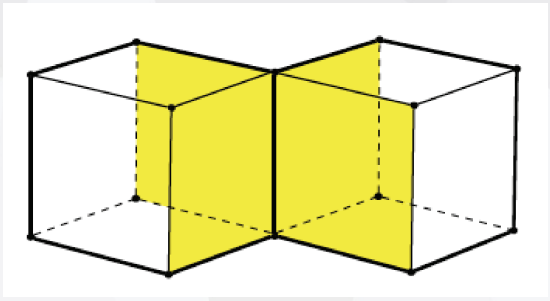
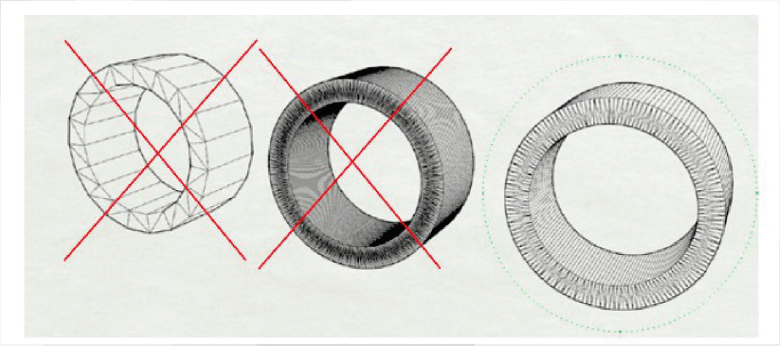
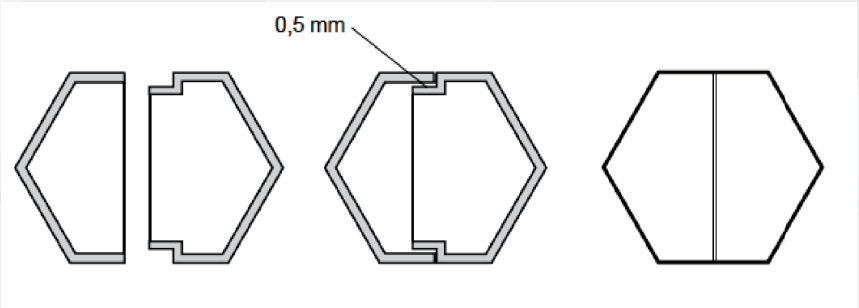
3D files - common mistakes

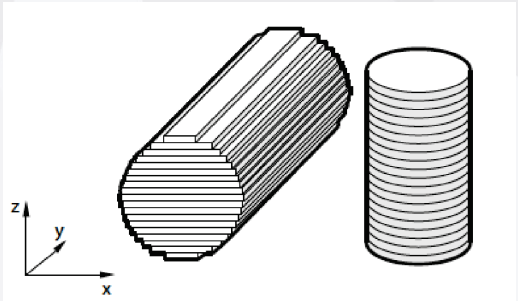


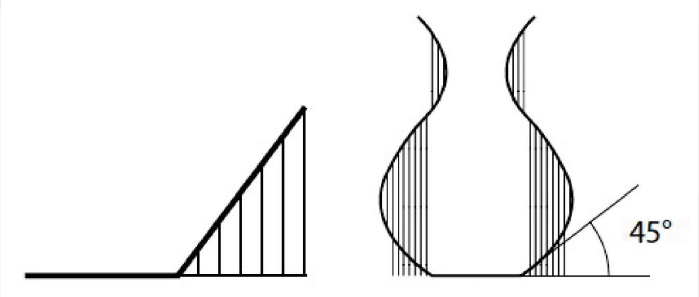




3D files - suggestions





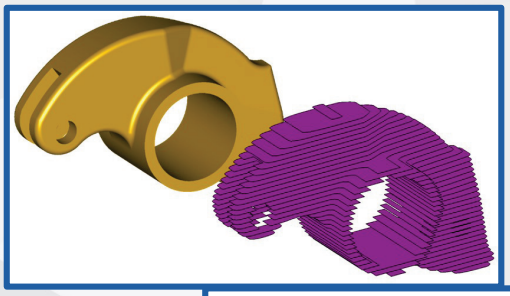


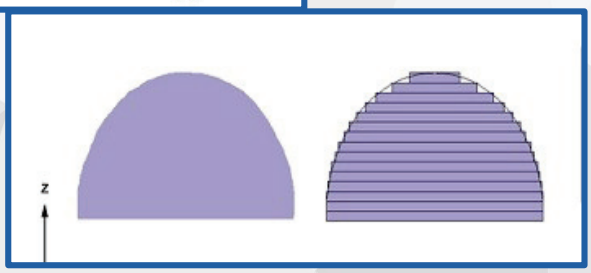
G-CODE and SLICING

G-code example

```
;Generated with Cura_SteamEngine 13.11.2
M109 T0 S227.000000
T0
;Sliced ?filename? at: Tue 26-11-2013 17:33:05
;Basic settings: Layer height: 0.2 Walls: 0.8 Fill: 20
;Print time: #P_TIME#
;Filament used: #F_AMNT#m #F_WGHT#g
;Filament cost: #F_COST#
G21     ;metric values
G90     ;absolute positioning
M107    ;start with the fan off
G28 X0 Y0  ;move X/Y to min endstops
G28 Z0     ;move Z to min endstops
G1 Z15.0 F?max_z_speed? ;move the platform down 15mm
G92 E0                  ;zero the extruded length
G1 F200 E3              ;extrude 3mm of feed stock
G92 E0                  ;zero the extruded length again
G1 F9000
M117 Printing...
;Layer count: 179
;LAYER:0
M107
G0 F3600 X87.90 Y78.23 Z0.30
;TYPE:SKIRT
G1 F2400 E0.00000
G1 F1200 X88.75 Y77.39 E0.02183
G1 X89.28 Y77.04 E0.03342
G1 X90.12 Y76.69 E0.05004
G1 X90.43 Y76.63 E0.05591
G1 X91.06 Y76.37 E0.06834
...
```

The Slicing process





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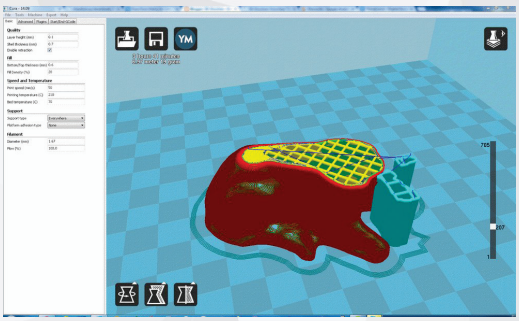
Main "slicing" softwares

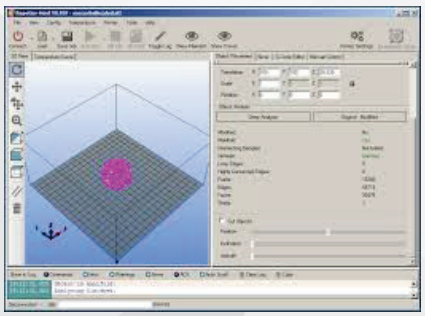
Cura

Powered by Ultimaker

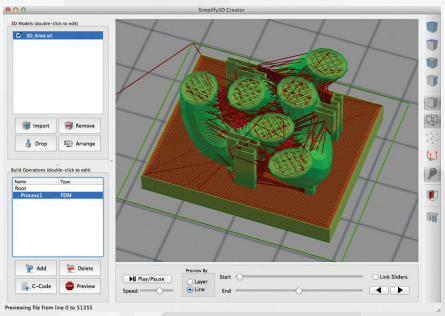


Slic3r

G-code generator



SIMPLIFY3D®



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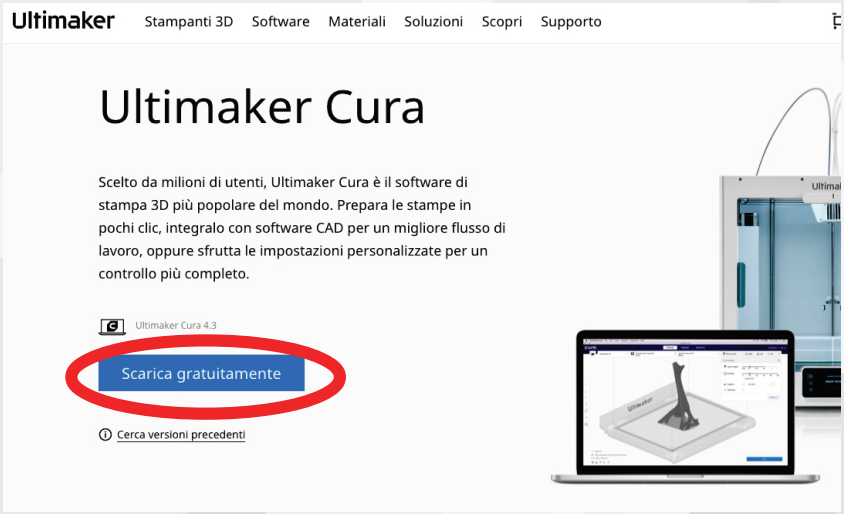
Slicing with Ultimaker Cura(4.3.0)

Ultimaker Cura is one of the most widely used silicing software, downloadable and installable for free.

Warning!
Some 3D printers, such as the Makerbot, have their own proprietary Slicing software.
The following concepts apply to all Slicing software, which will have different menus and interfaces



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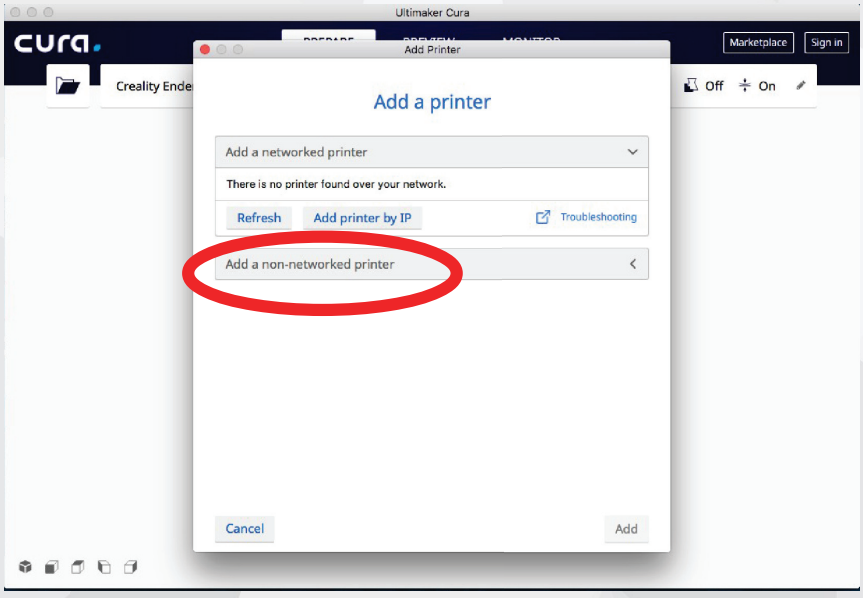
Slicing with Ultimaker Cura(4.3.0)

First of all, the newly installed software asks you to add a printer, which can be networked (it will appear among those identified) or non-networked (red circled)



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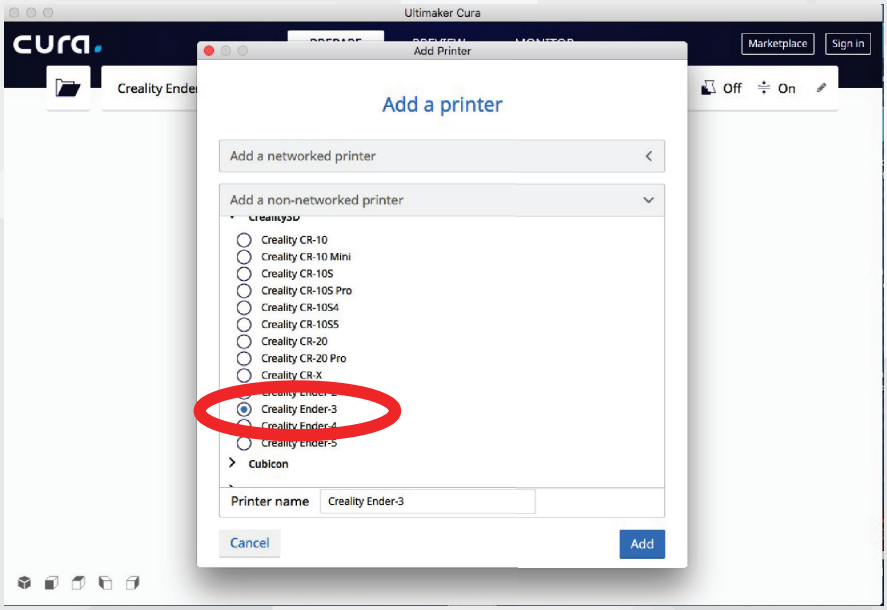
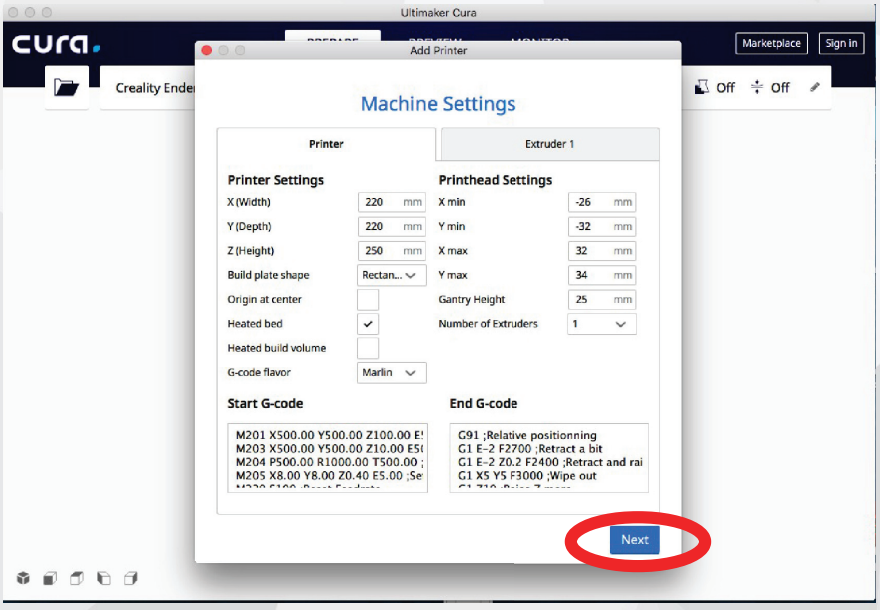
Slicing with Ultimaker Cura(4.3.0)

You can choose a 3D printer from those listed. In the example, circled in red, we chose a Creality Ender-3. (If your printer is not on the list you can also create a new one; you will need to know at least the printer size and diameter of the nozzle and filament used).



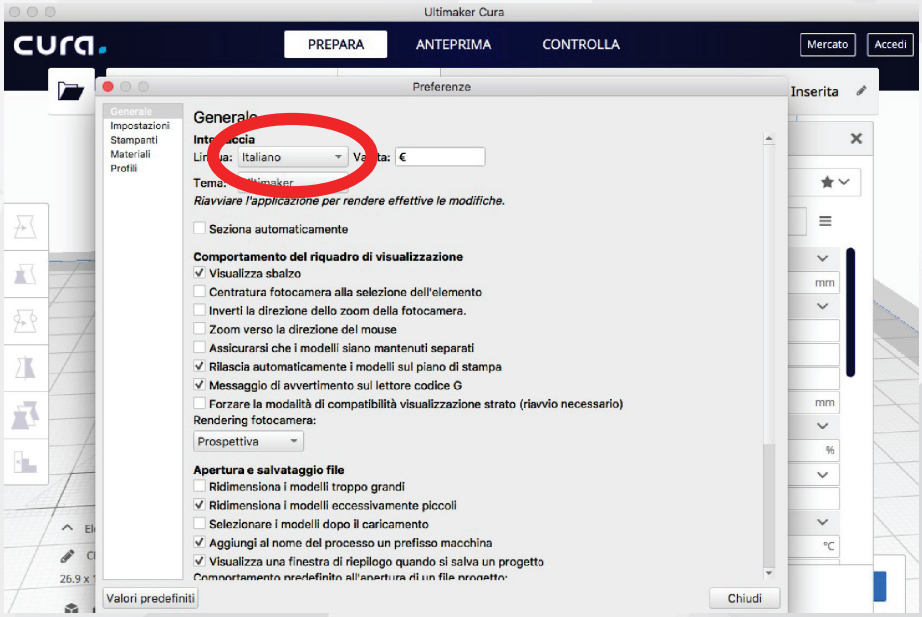
Slicing with Ultimaker Cura(4.3.0)

A window will appear with the summary of the characteristics of the selected machine, in two or more sheets: printer and extruder (1, 2 etc).
Usually everything can be left as we find it.



Slicing with Ultimaker Cura(4.3.0)

If we want, we can change the language of CURA in the general preferences screen (then we need to restart CURA)



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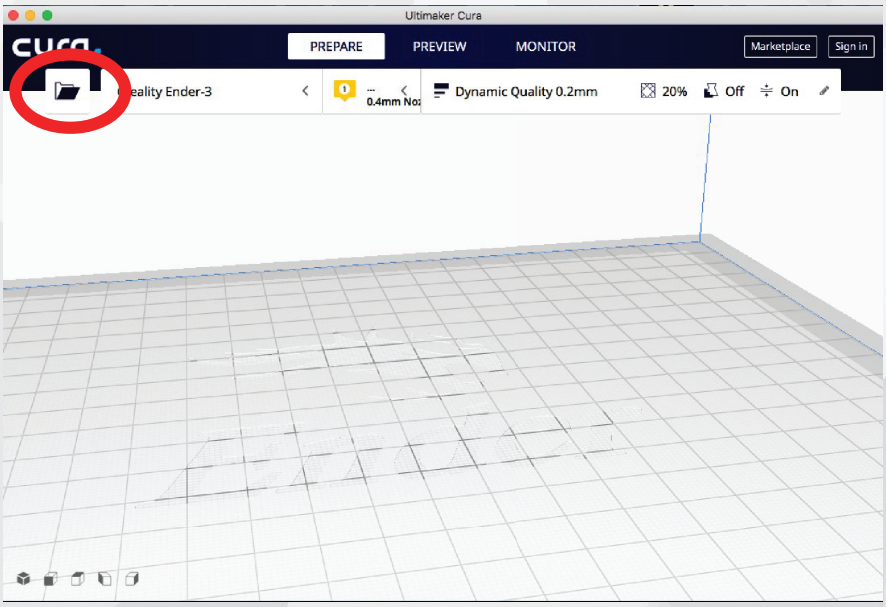
Slicing with Ultimaker Cura(4.3.0)

We can import a 3D file by clicking on the usual icon (circled in red in the image)
It is advisable to use the STL format, now a standard for this type of application.

(You can find the 3d model used in the following slides here: https://www.thingiverse.com/thing:40212/files)



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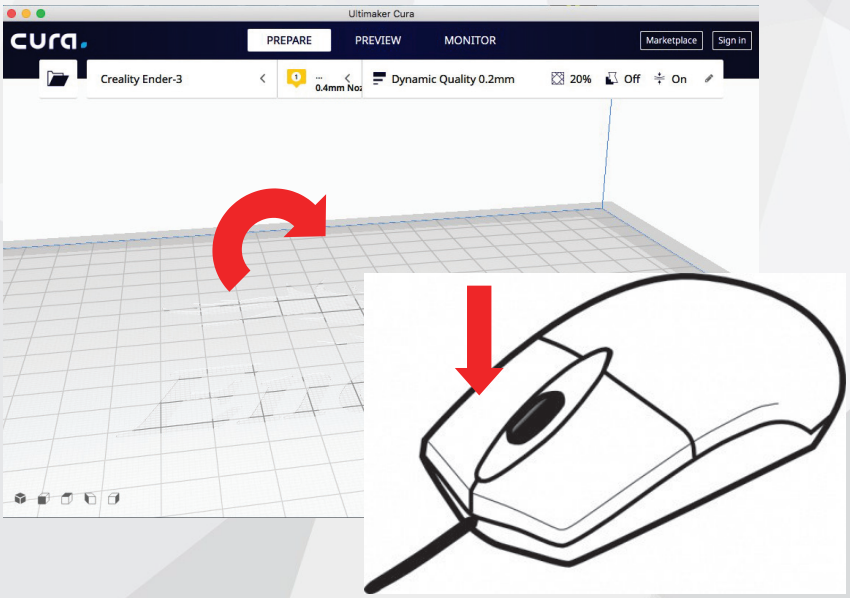
Slicing with Ultimaker Cura(4.3.0)

Using Cura, if we hold down the right mouse button and move the mouse itself, we rotate of the 3D world (printing volume) ...



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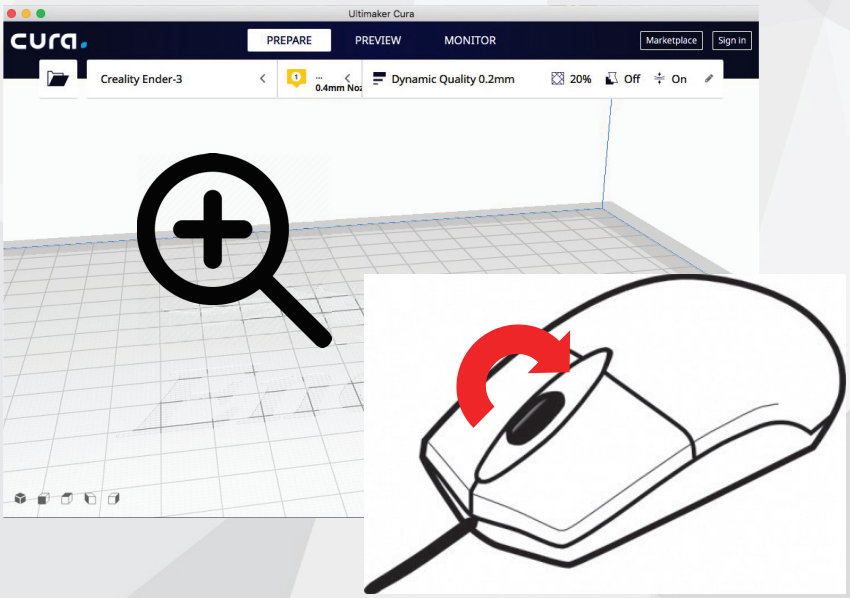
Slicing with Ultimaker Cura(4.3.0)

...if we rotate the mouse wheel, we "zoom in" and out...



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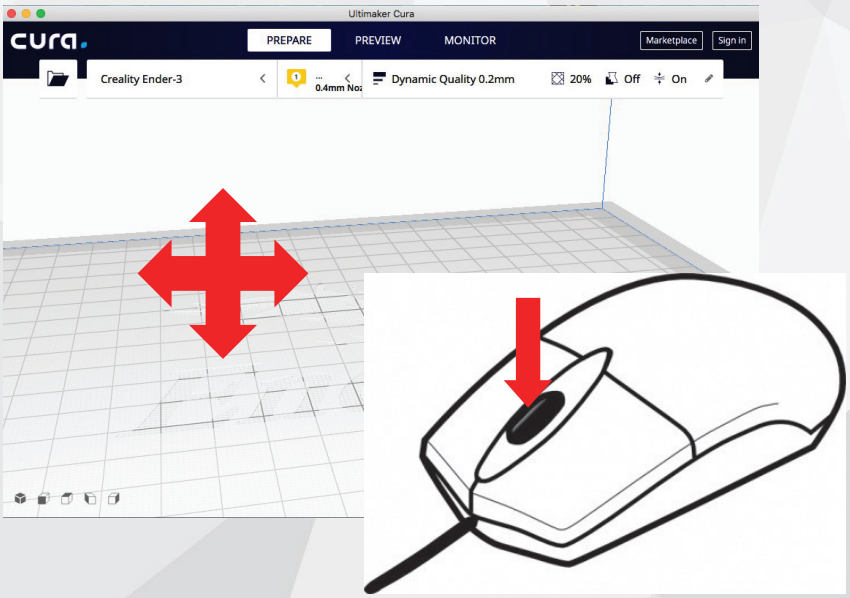
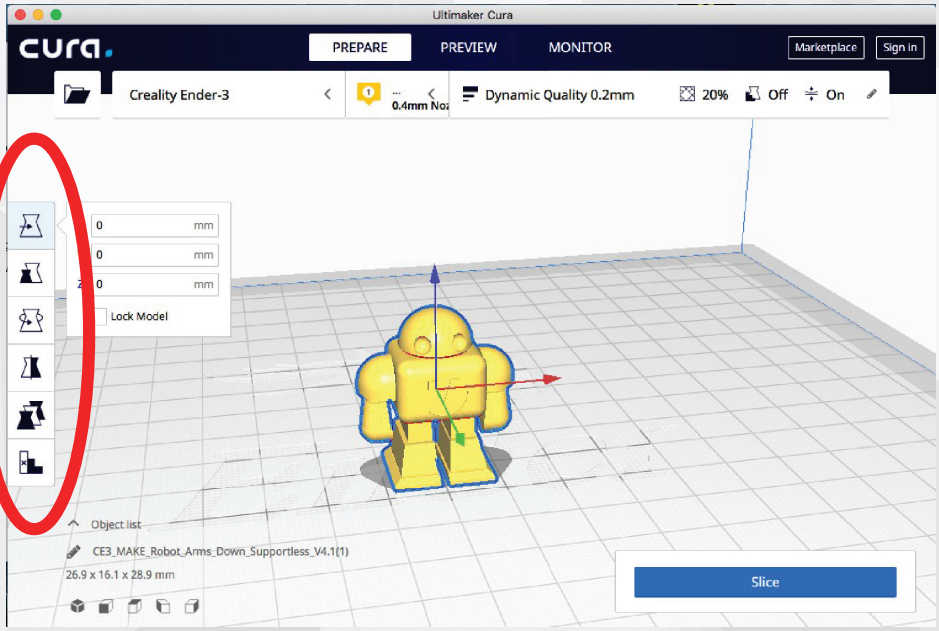
Slicing with Ultimaker Cura(4.3.0)

...if we keep the wheel pressed and move the mouse, we will move the three-dimensional world without rotating it



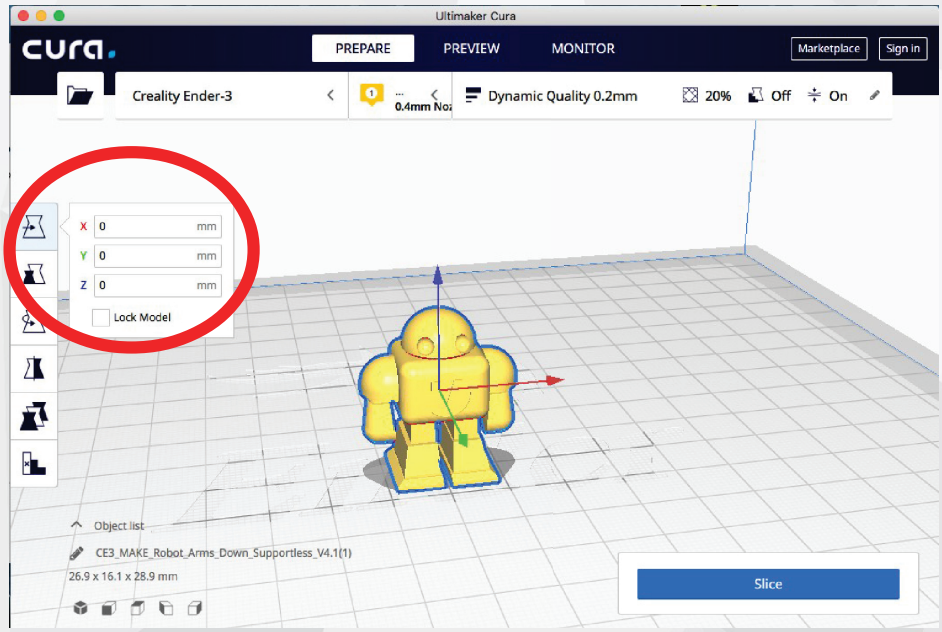
Slicing with Ultimaker Cura(4.3.0)

The imported model will appear in yellow in the middle of the printing volume. If we select it, by clicking it, the icons circled in red in the image will become active.



Slicing with Ultimaker Cura(4.3.0)

The first icon at the top will activate the function of moving the model, in three directions: X, Y and Z.
By default, the model is positioned in the center; it will be moved only if needed (eg simultaneous printing of several objects)



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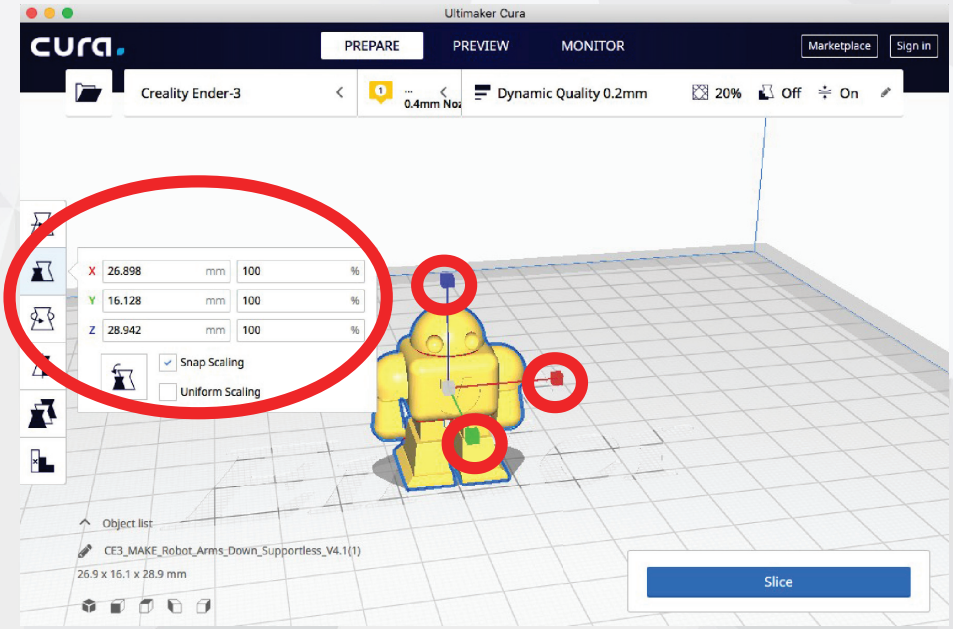
Slicing with Ultimaker Cura(4.3.0)

The second icon activates the model scaling function. We will see listed the three dimensions in mm and the percentages (initial value = 100%).
We can scale uniformly or non-uniformly ("uniform scaling" with or without flags), entering numeric values or pulling the cubes with the cursor on the model



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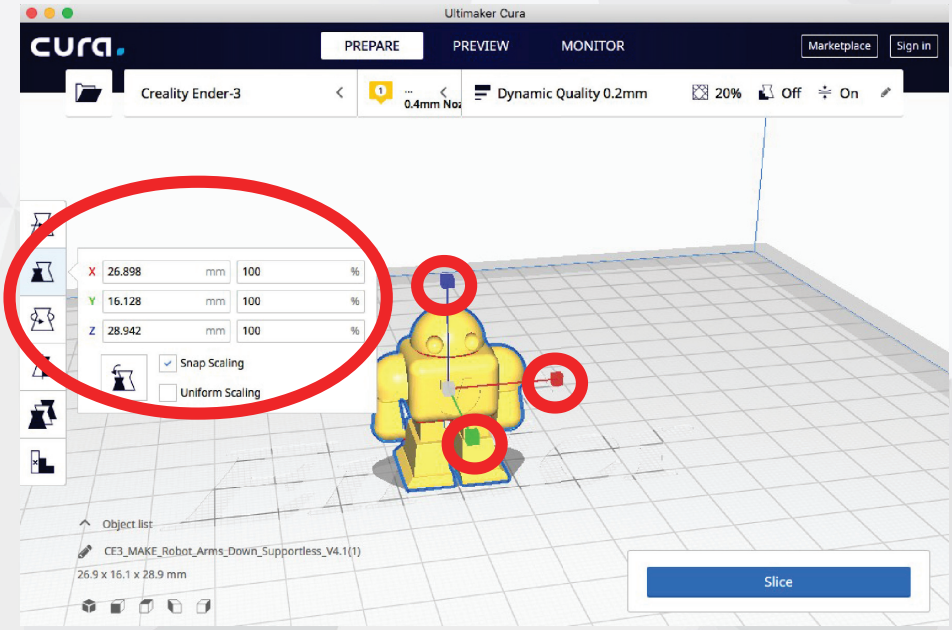
Slicing with Ultimaker Cura(4.3.0)

The scaling of an object is a useful function for educational purposes, because it allows to deepen the topic of the cube of a dimension.
(For example: how much does the volume of an object increase if you double its dimensions uniformly in X, Y and Z?)



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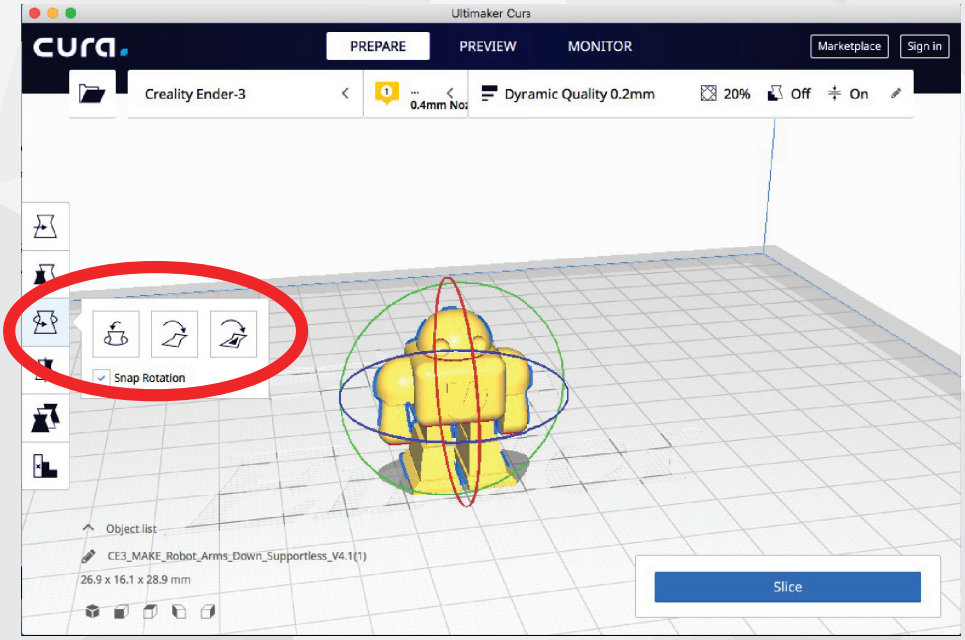
Slicing with Ultimaker Cura(4.3.0)

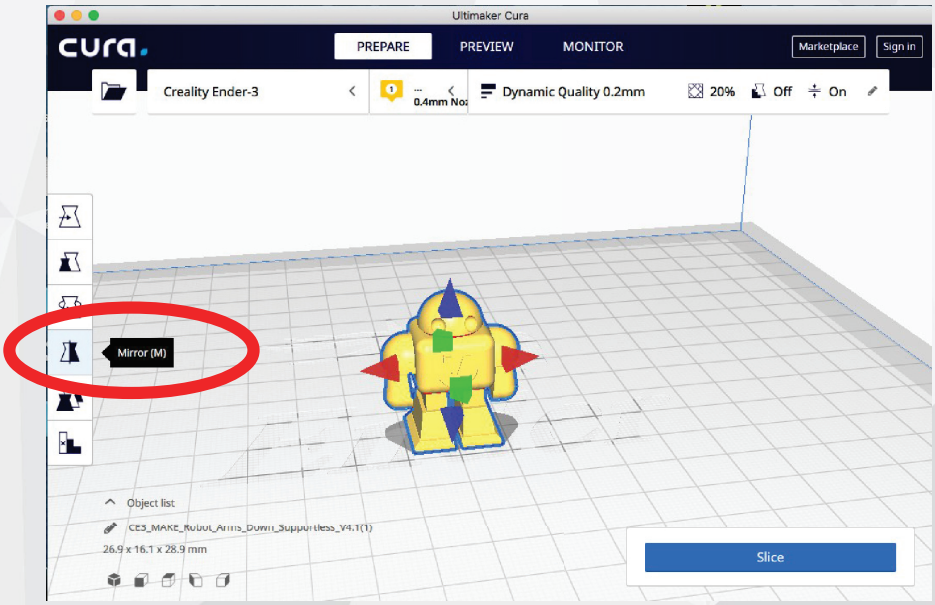
The third icon activates the rotation function of the model. 3 colored circles appear which are used to rotate the model with respect to the three main axes.
The rotation of the model can be fundamental for the aesthetic and functional outcome and to optimize printing times.



FAB LAB PALERMO

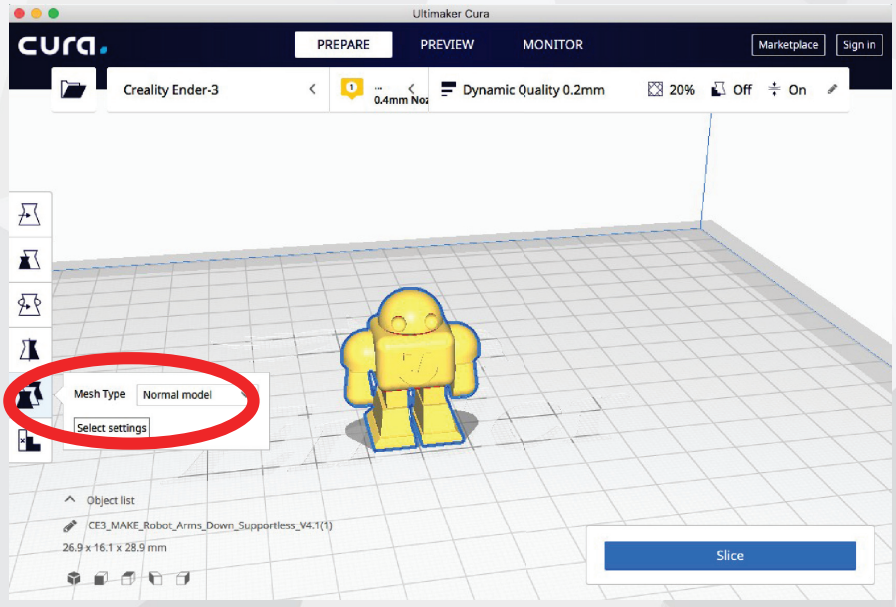
Slicing with Ultimaker Cura(4.3.0)

The fourth icon activates the mirroring function of the model, useful when the model has no symmetry plans and you want to obtain a mirrored model, for example a "left" if you have a "right".



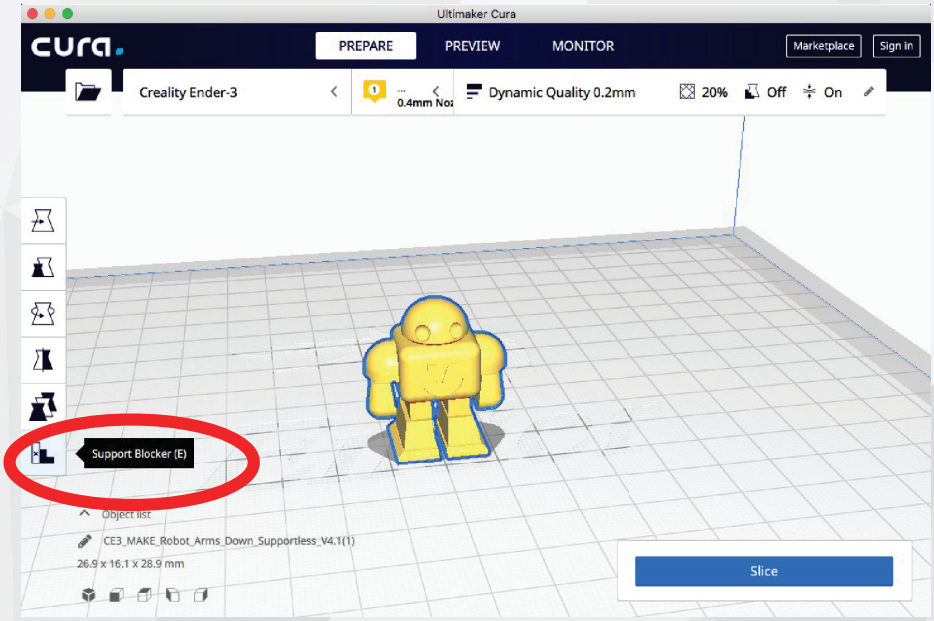
Slicing with Ultimaker Cura(4.3.0)

The fifth icon gives access to the functions whose use is beyond the scope of this course.



Slicing with Ultimaker Cura(4.3.0)

The sixth icon activates the function of creating the "media block", ie it allows you to create virtual volumes, within which the creation of "supports" will be inhibited. We will deepen later the concept of supports and its use. These volumes can be moved, scaled and rotated as the model to be printed.



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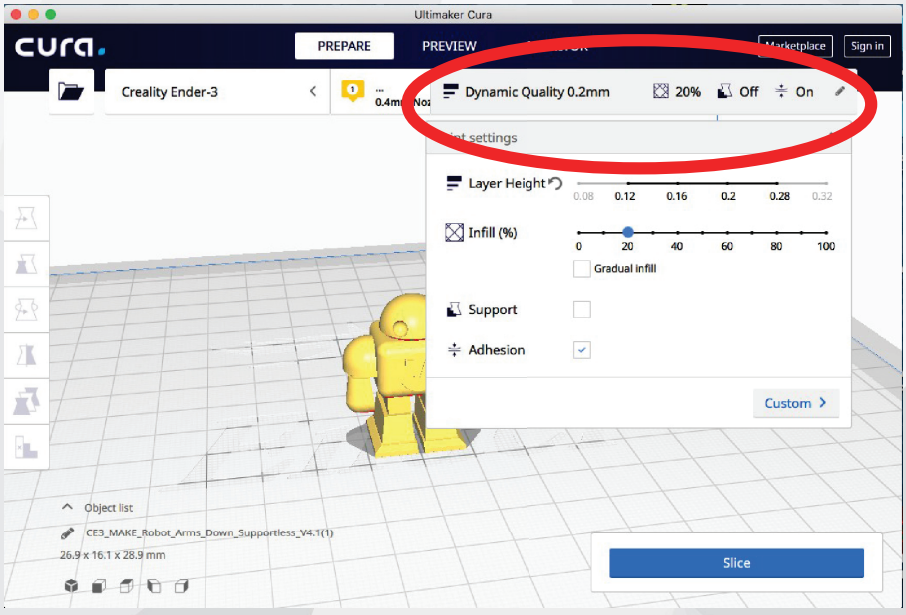
Slicing with Ultimaker Cura(4.3.0)

UOnce any action on the model have been chosen using the icons described up to this point (we can return to using them at any time), we proceed with the settings of the printing parameters, through the menu that can be activated via the bar circled in red



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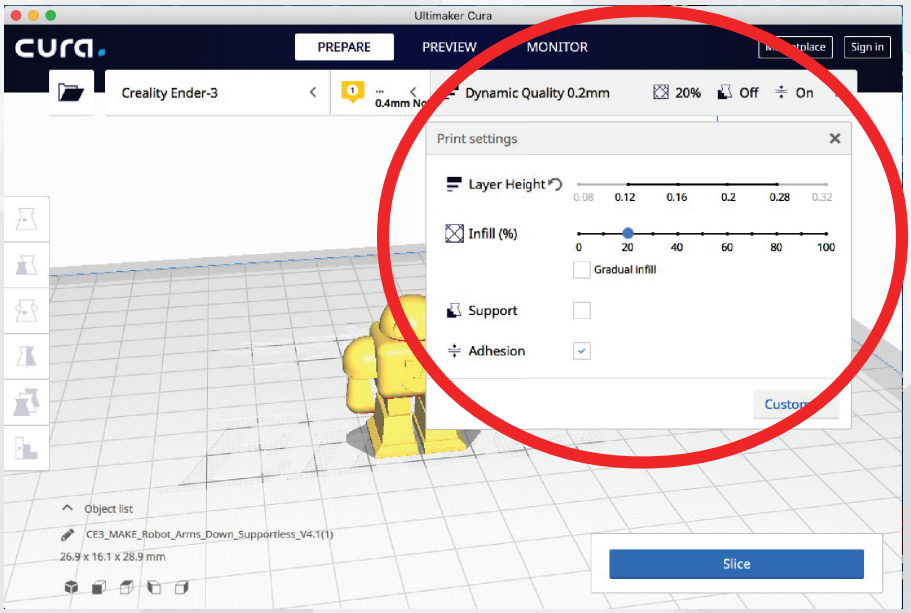
Slicing with Ultimaker Cura(4.3.0)

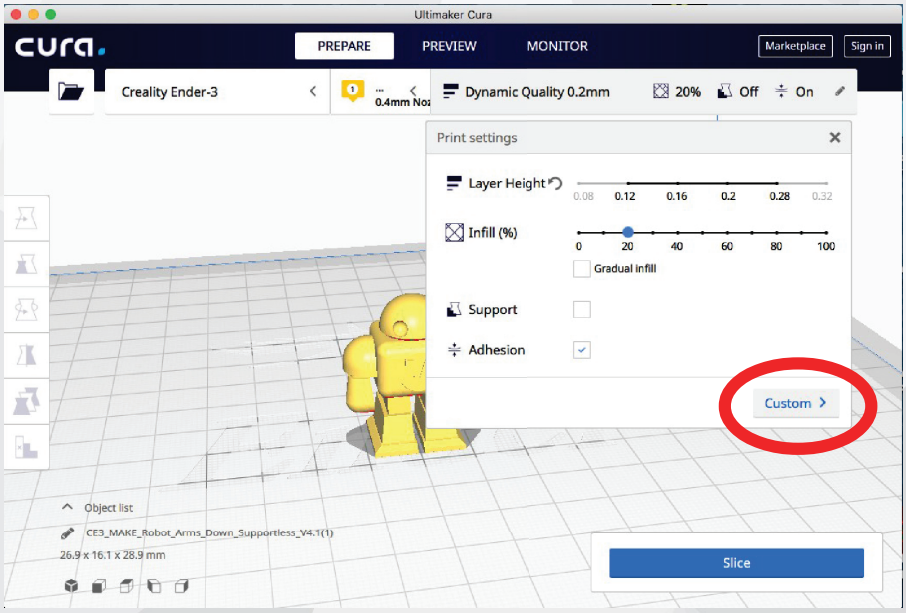
The menu that appears by default is the "Recommended" menu, which is very simplified, as it contains only a few basic parameters:
Layer height,
Infill (%)
Support
Adhesion

...



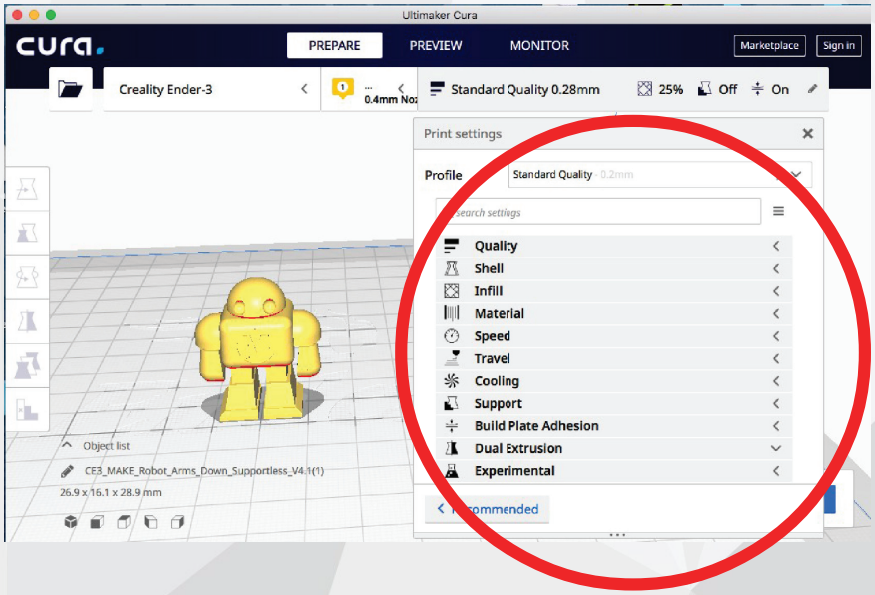
Slicing with Ultimaker Cura(4.3.0)

...
To deepen the printing settings it is more useful to switch to a more detailed menu by clicking on "Custom", at the bottom of the menu.



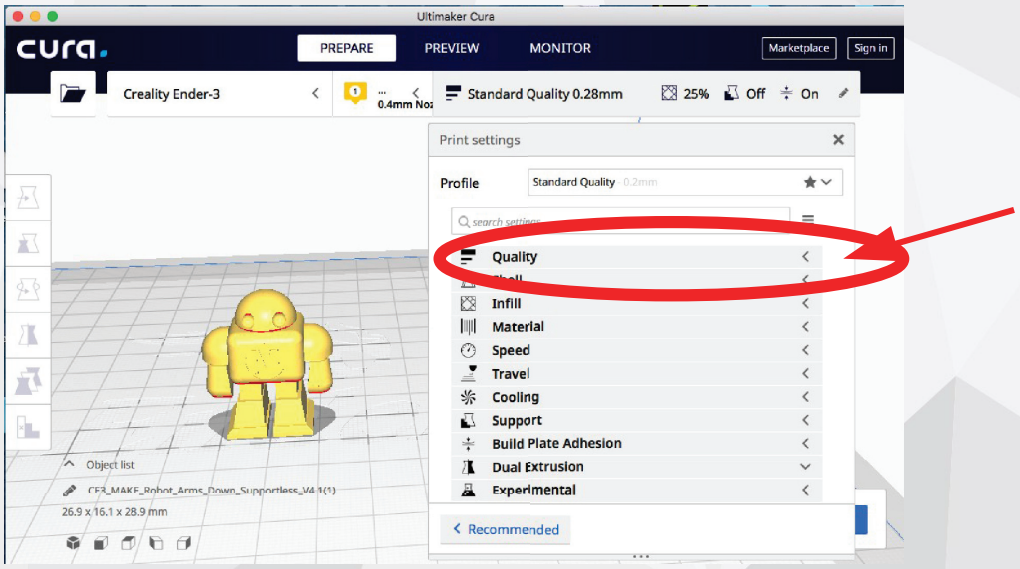
Slicing with Ultimaker Cura(4.3.0)

We will find a list of topics, each of which contains printing parameters. We can return to the simplified version at any time by clicking on "recommended".



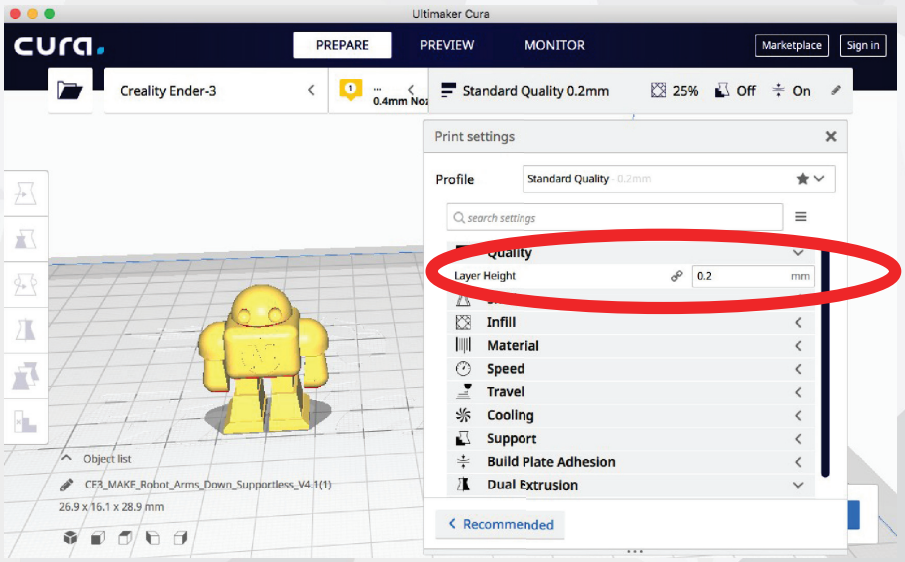
Slicing with Ultimaker Cura(4.3.0)

Clicking on the symbol marked by the arrow in the figure, we expand the first submenu, related to the "quality" topic



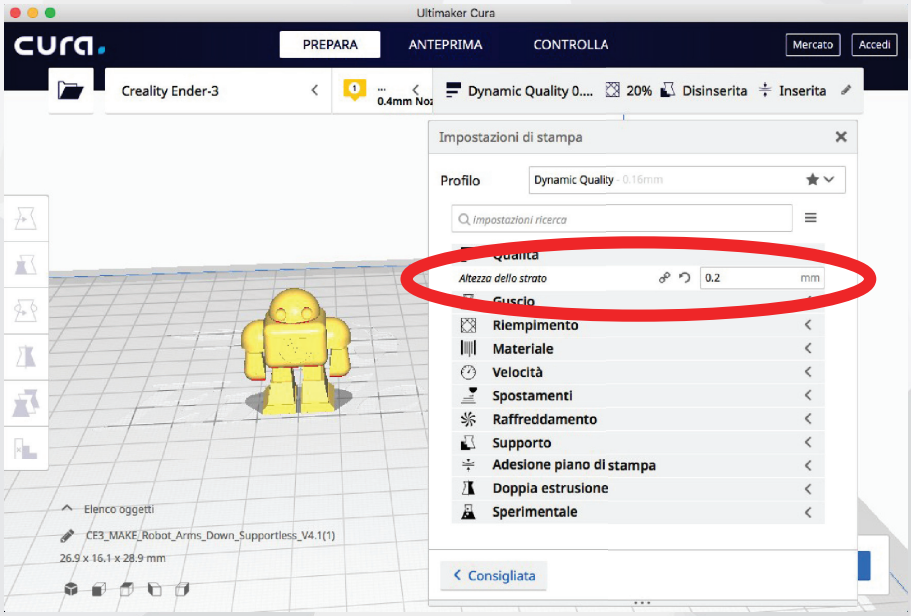
Slicing with Ultimaker Cura(4.3.0)

The parameter that appears is "layer height". This is the basic parameter for the quality of 3D printing and also affects printing times.
Since the print always proceeds in layers, this is the value in mm of the height of these. The lower this value, the more uniform and close the print will be compared to the digital 3D model ...



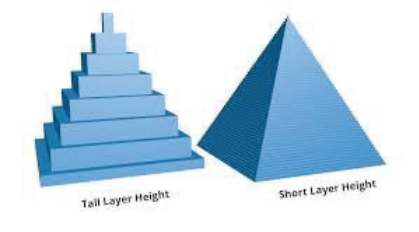
Slicing with Ultimaker Cura(4.3.0)

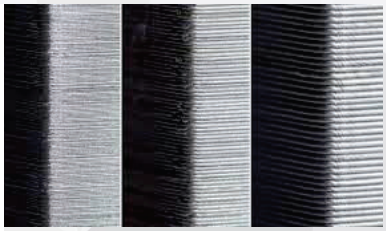
...
The height of the layer is equivalent to the size of the pixel in the resolution of a photo.
Its value in mm is related to the diameter of the hole of the printing nozzle, that is the thread of extruded material. Usually this diameter is 0.4mm, so we won't be able to have layers higher than this value, because we would create voids.



Slicing with Ultimaker Cura(4.3.0)

In these images, several examples and graphical representations of how the layer height affects the outcome of a 3D print. Printing with a standard 0.4mm nozzle, the recommended range of values of this parameter can be from a minimum of 0.1mm to a maximum of 0.3mm.





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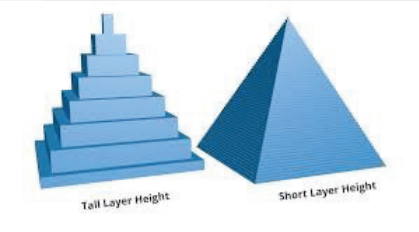
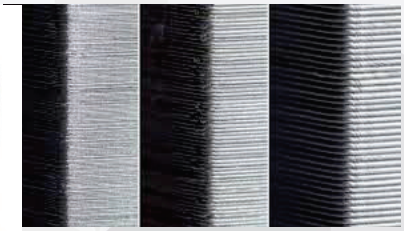
Slicing with Ultimaker Cura(4.3.0)

The layer height also influences the printing times, since as the height of the layer decreases the number of layers increases, each of which requires a printing time. Going from a layer height of 0.2mm to a layer of 0.1mm, will approximately double the total printing time





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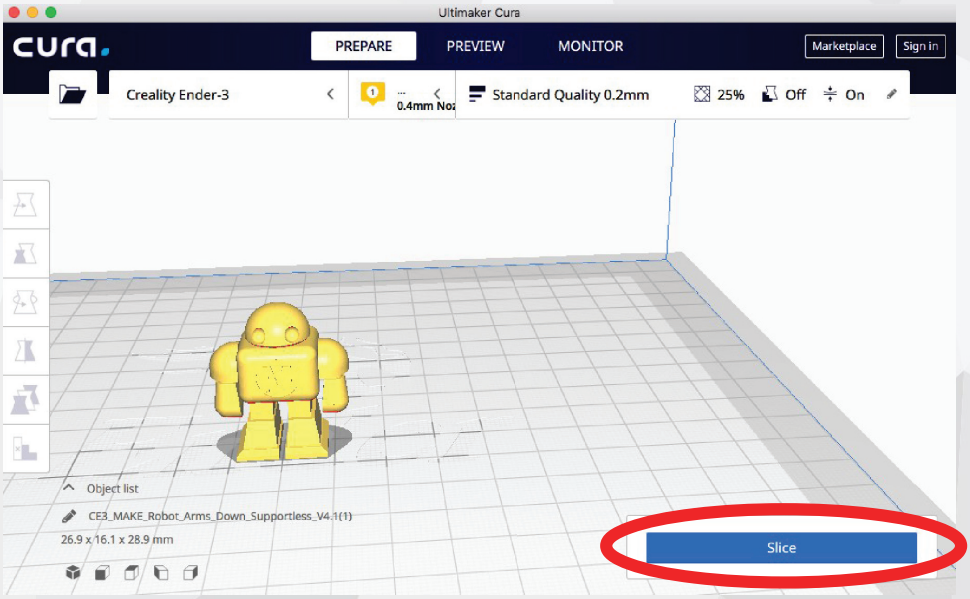
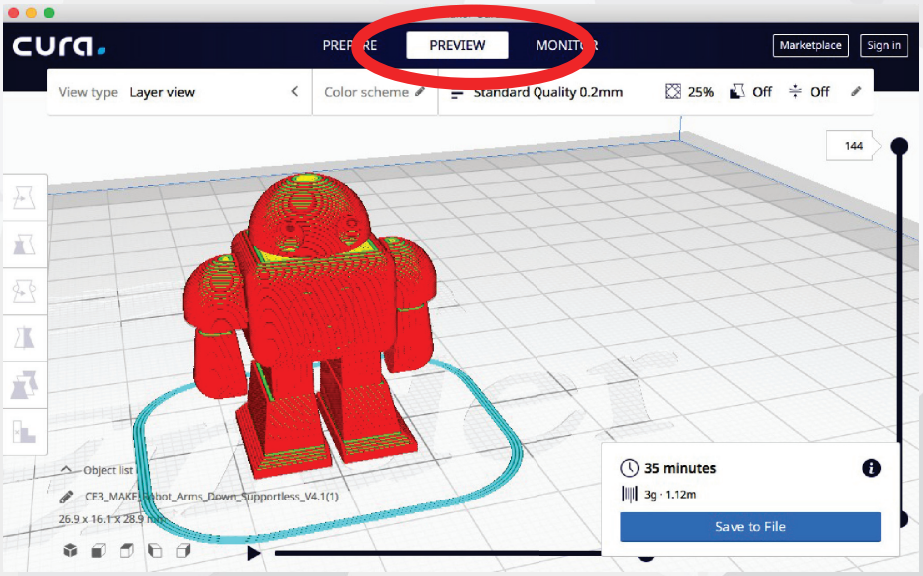
Slicing with Ultimaker Cura(4.3.0)

Before going on with the other settings, let's try making a first "slicing", clicking on "sectioning", circled in red in the figure.



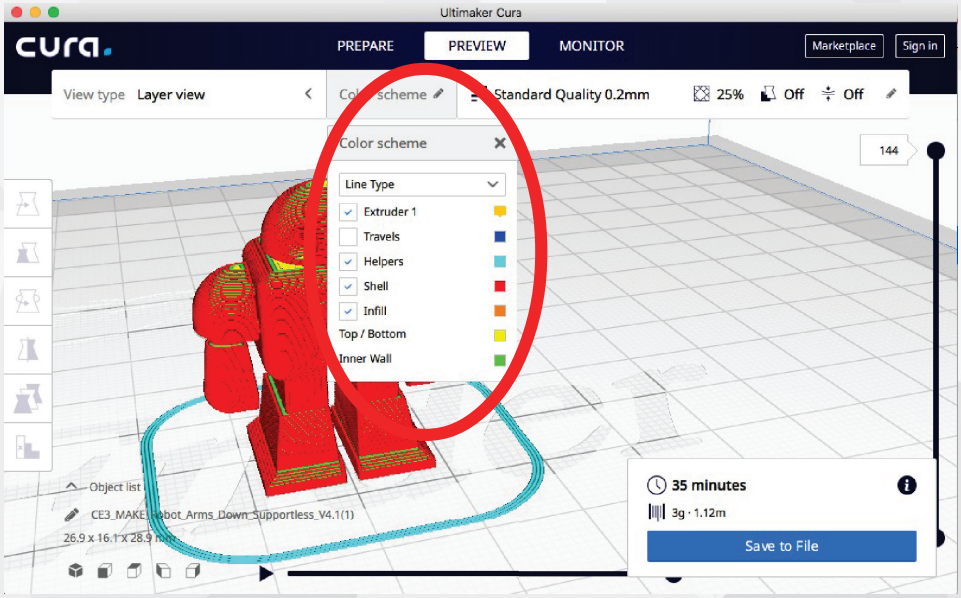
Slicing with Ultimaker Cura(4.3.0)

By clicking on "Preview", we will be able to see how the print layers will look, exactly as they will be created by the 3D printer.



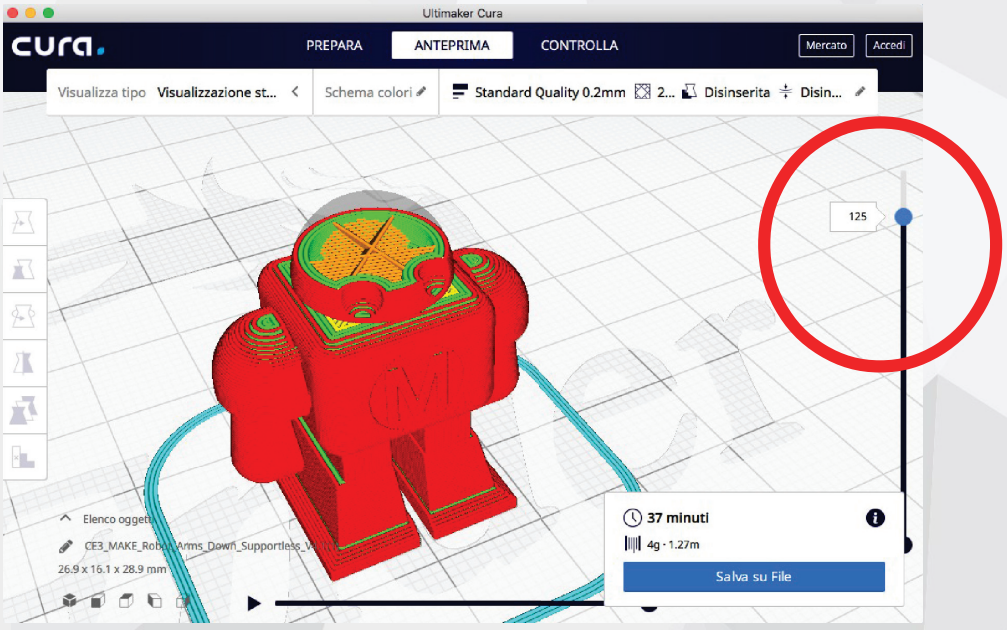
Slicing with Ultimaker Cura(4.3.0)

For the best preview, we advise you to click on "color scheme" and choose "line type". In this way we will see the various phases of the extrusion that make up the layers, distinguished by color: red will be the external shell, orange will be the infill, etc.



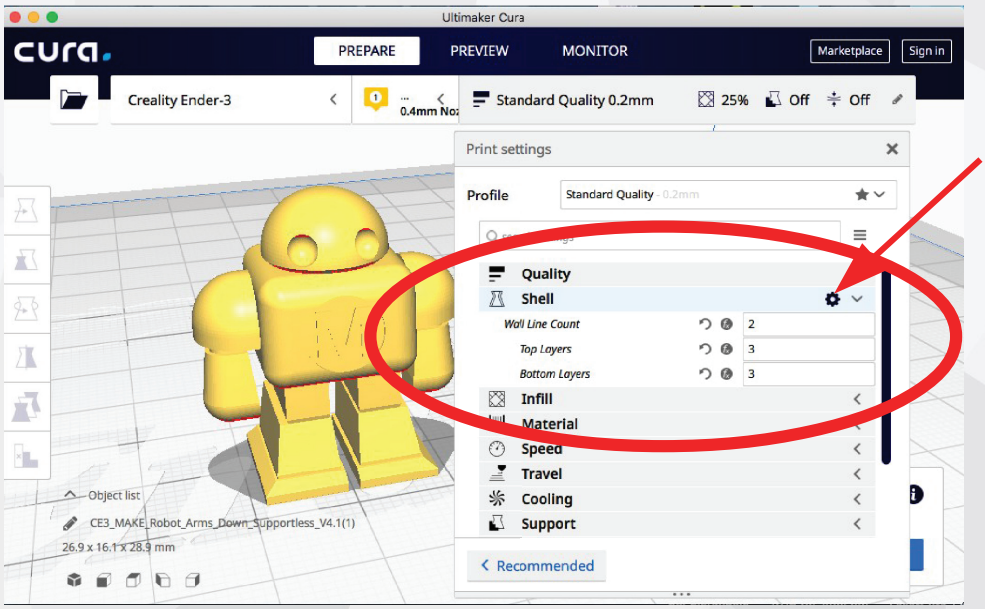
Slicing with Ultimaker Cura(4.3.0)

Through the bar circled in red, we can navigate between the various layers and observe all the internal and external extrusions that will be created, in order to visualize any changes to the printing parameters.



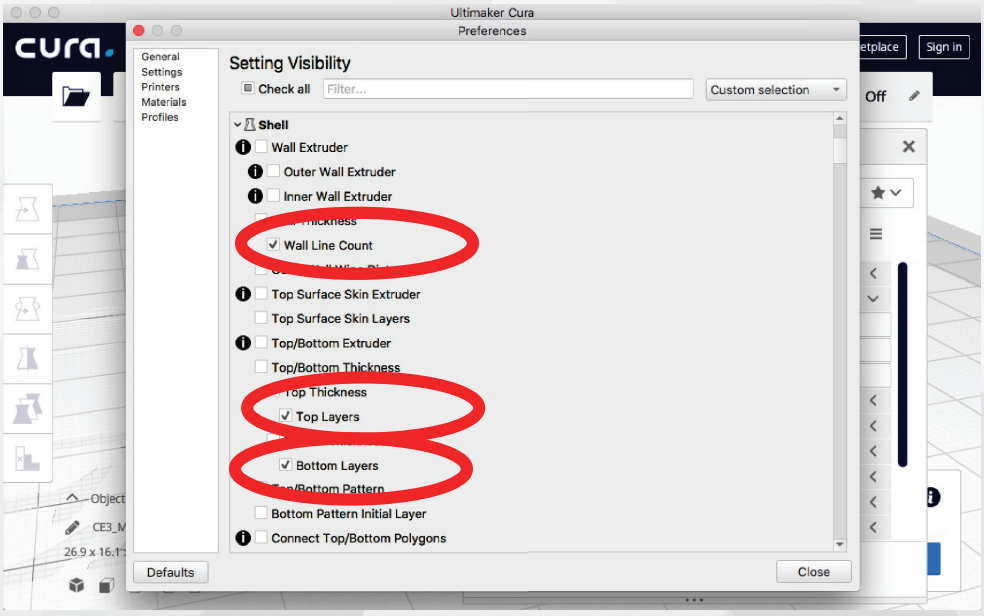
Slicing with Ultimaker Cura(4.3.0)

Going back to the print parameters, let's go to the "Shell" menu. Expanding it, you will probably see different parameters than the ones shown here, which we suggest you use. Then click on the gear shaped icon highlighted by the red arrow.



Slicing with Ultimaker Cura(4.3.0)

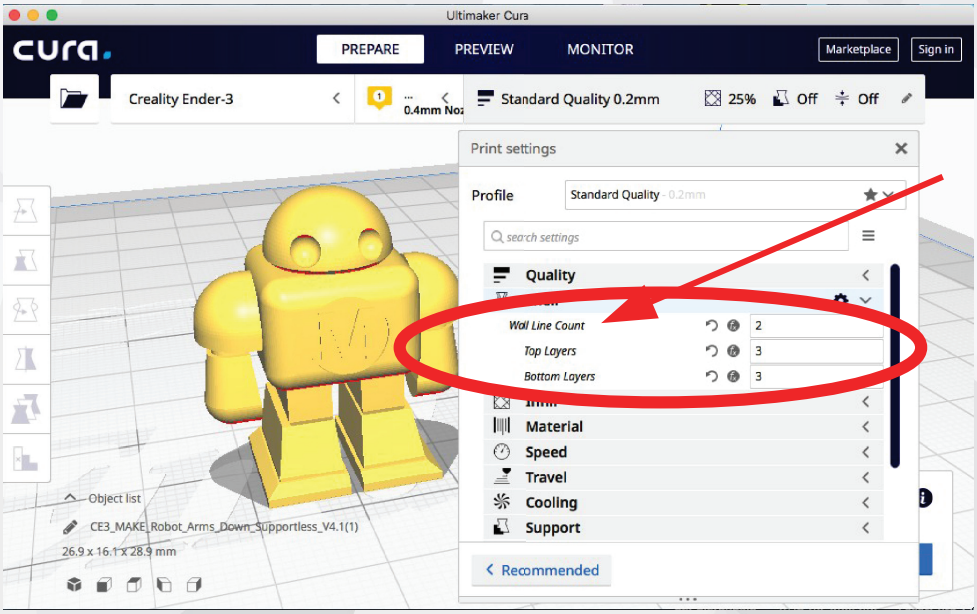
The preferences window will appear, where we can remove or put the "flags" to show or hide the parameters we want to set. For the "Shell" menu, we recommend to set the flag only on:
- Wall Line Count
- Top layers
- Bottom layers



Slicing with Ultimaker Cura(4.3.0)

We will then find in the menu "Shell" only the three parameters just selected.
The first is:
- Wall line count

This value sets the number of walls that the printer will make, at each layer, to build the perimeter walls of our three-dimensional model.



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Slicing with Ultimaker Cura(4.3.0)

To better understand the meaning of this parameter, try to set it to the value 3 and then click on "slice", then on "preview" and set the sidebar to see an intermediate layer of our object.
Let's do the same thing with the parameter set to 1 and 8.

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Slicing with Ultimaker Cura(4.3.0)

In the three previews you will clearly see what the 3 different values mean:

3 = 3 wall lines (we will see the external red and the other two green)

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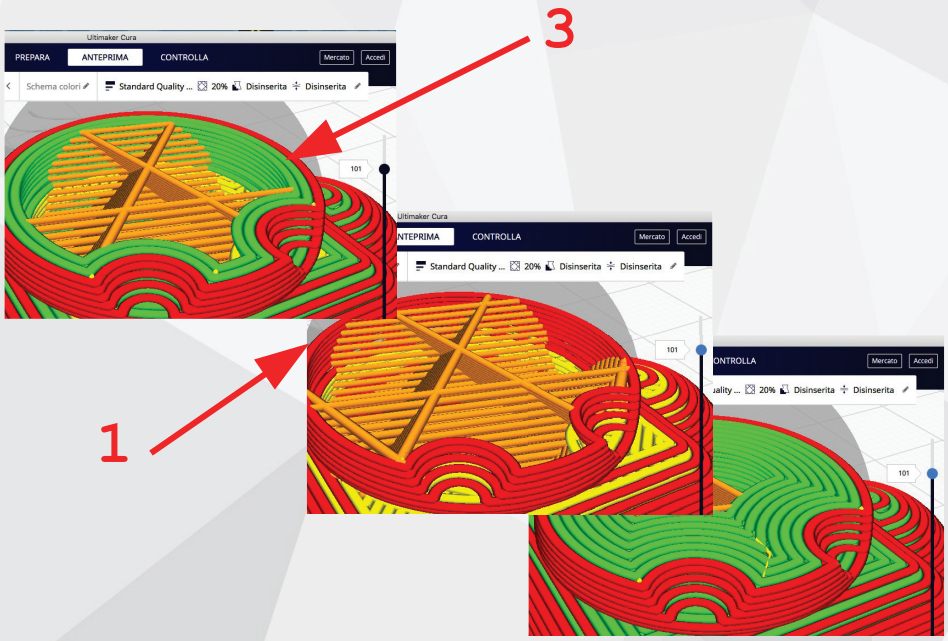
Slicing with Ultimaker Cura(4.3.0)

In the three previews you will clearly see what the 3 different values mean:

1 = 1 wall line (we will see just the external red)



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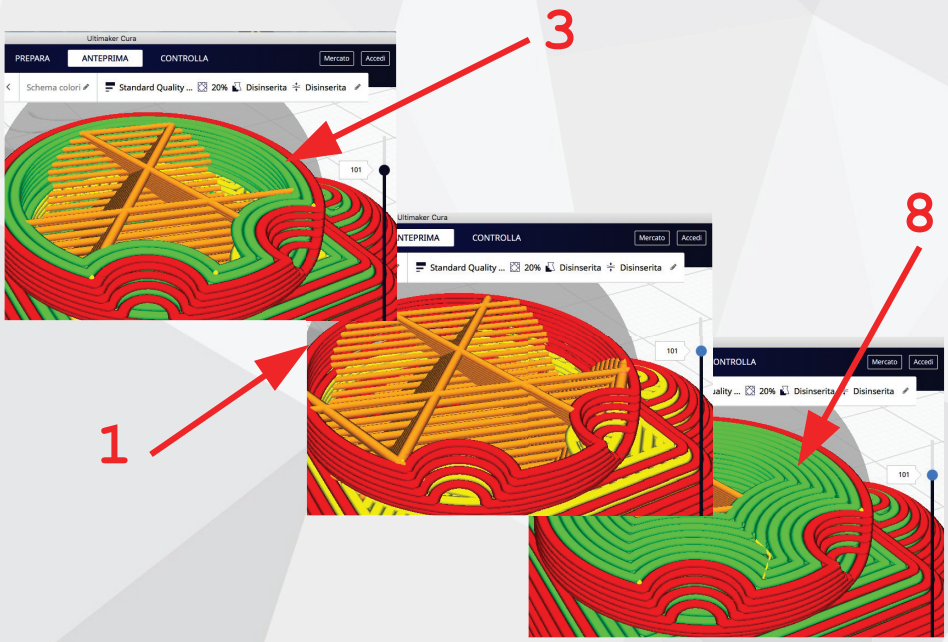
Slicing with Ultimaker Cura(4.3.0)

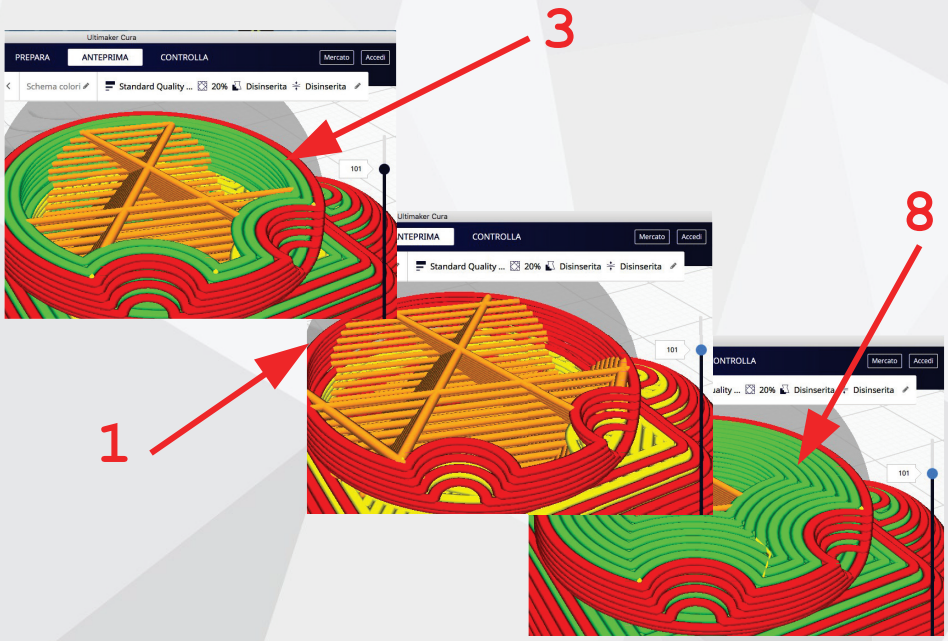
In the three previews you will clearly see what the 3 different values mean:

8 = 8 wall lines (we will see the external red and the other 7 green)



Slicing with Ultimaker Cura(4.3.0)

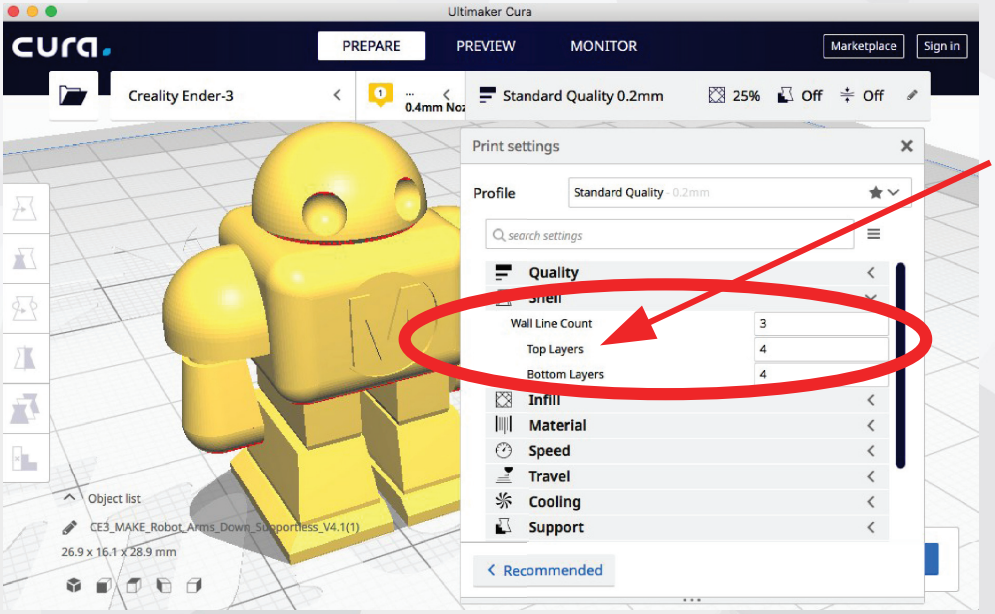
The number of "wall lines" is very important for the strength of the object that we will print and also for the quality of the external surface. The most frequently used values range from a minimum of 2 to a maximum of 4, with a recommended average value of 3.



Slicing with Ultimaker Cura(4.3.0)

The following parameters to be set in the "Shell" menu are:
- Top layers
- Bottom layers

The assigned value will determine the number of "solid" layers that will be printed every time there are areas in the model with horizontal shell.



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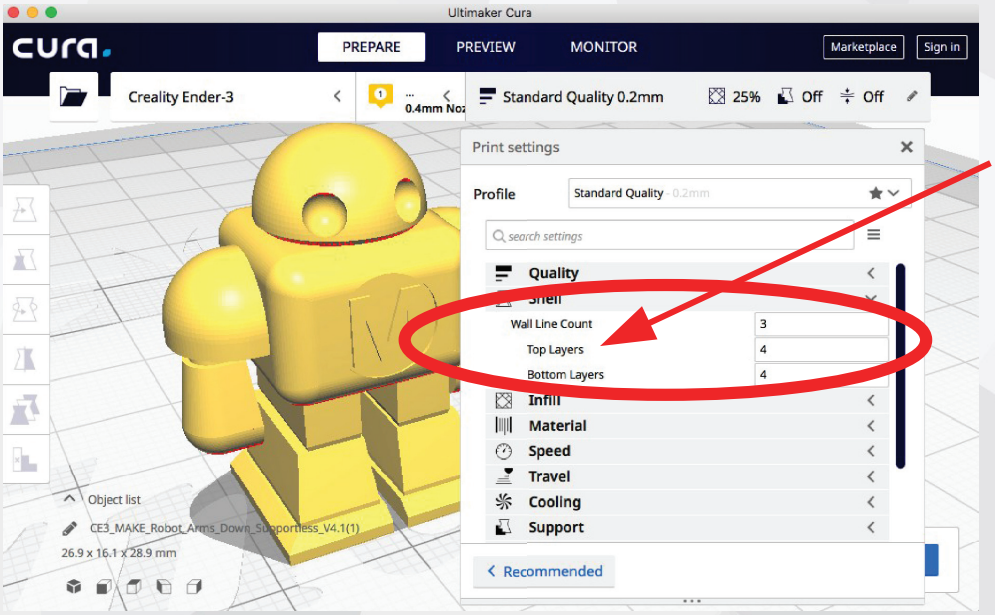
Slicing with Ultimaker Cura(4.3.0)

For these parameters, the most frequently used values are quite similar to those used for the number of wall lines or slightly higher. The set of values in the image next here (3,4,4) is advisable.



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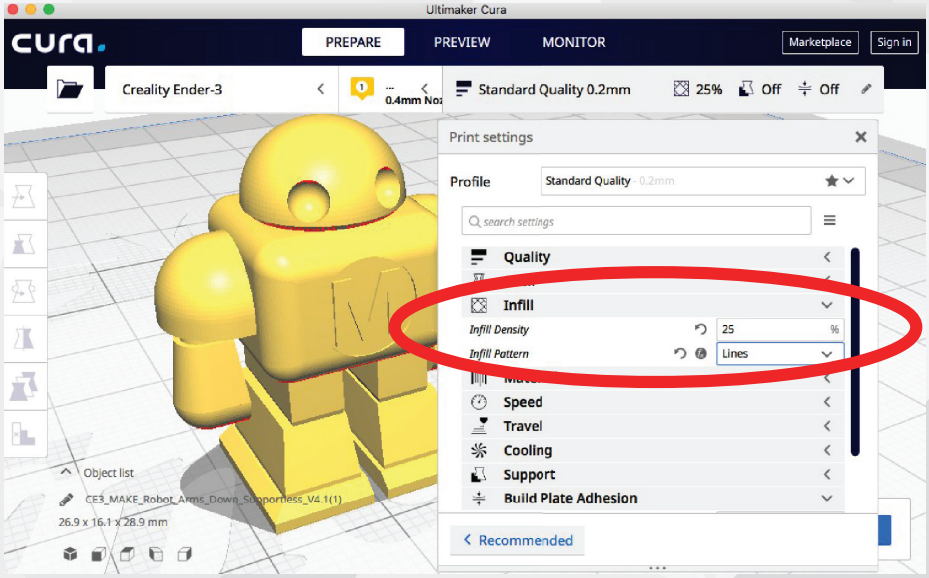
Slicing with Ultimaker Cura(4.3.0)

The next menu is "Infill" and allows you to set the percentage value of material that will be extruded to fill the inner part of our 3D model, that is, everything that is not "shell".
We can set the percentage value and the type of configuration (Grid, Cubes etc.)

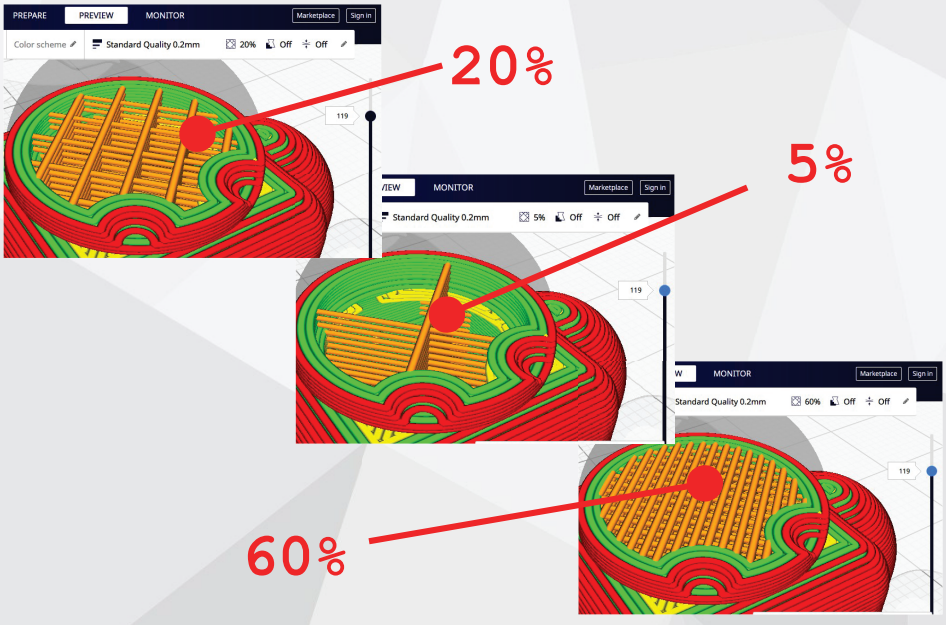


Slicing with Ultimaker Cura(4.3.0)

In the images next here, the previews where you can see, in orange, three different "infill" percentages:

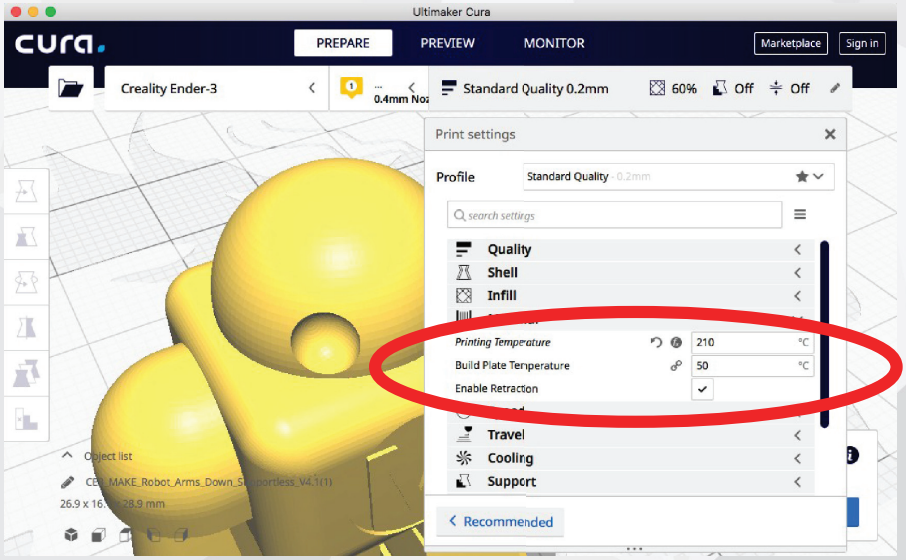
20%
5%
60%

As this parameter varies, the 3D printed model will be more strong but will take longer to be printed. The most used values range from 10% to 35%.



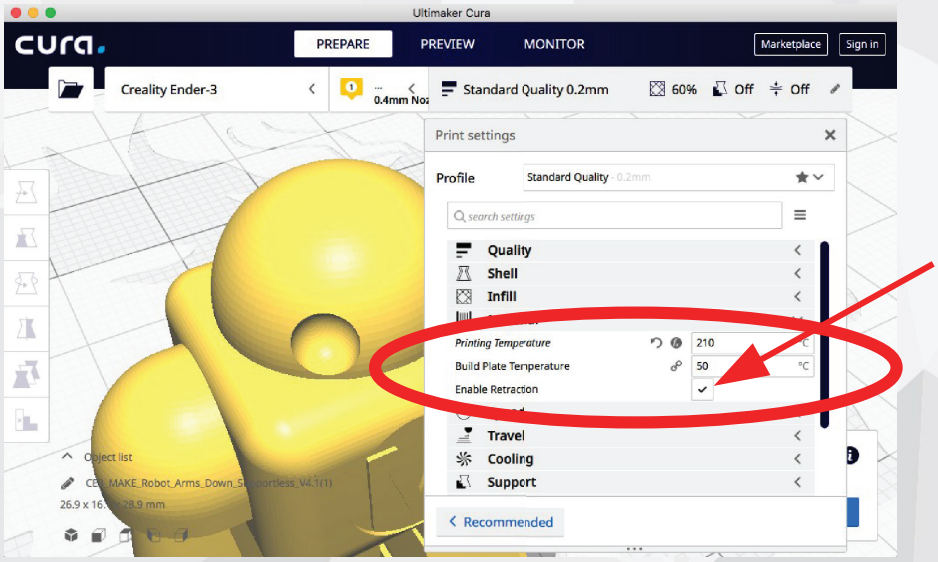
Slicing with Ultimaker Cura(4.3.0)

The next menu is "Material" and allows you to set the extrusion temperature and the heated bed values, which vary with the filament material. These values are often shown on the filament packaging.
For the PLA you can use:
200-210 ° C (printing)
50 ° C (floor)



Slicing with Ultimaker Cura(4.3.0)

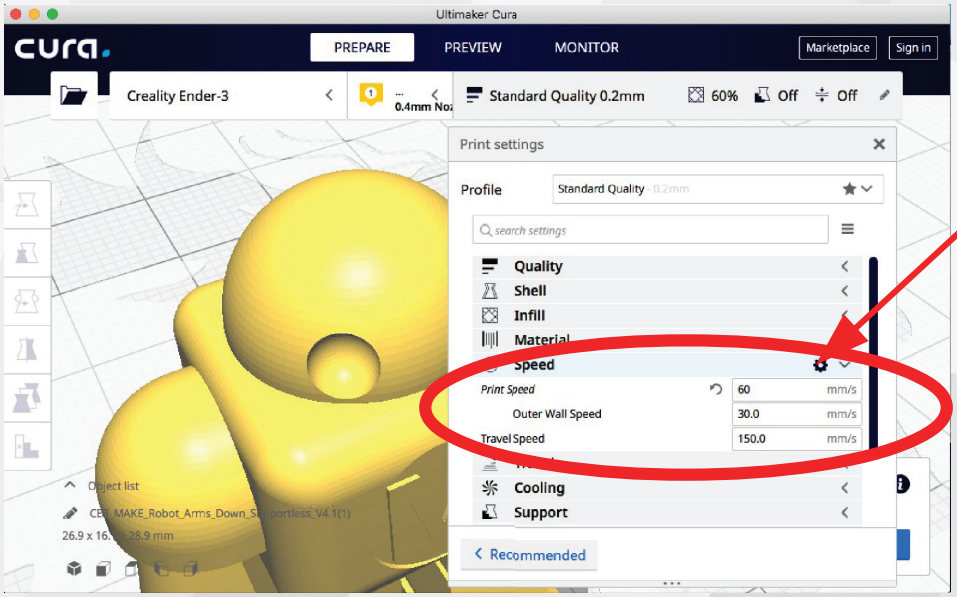
"Enable retraction" allows you to enable or disable a retraction movement of the filament that prevents the creation of small threads when the nozzle moves without extruding.
It is advisable to disable retraction only when printing flexible materials



Slicing with Ultimaker Cura(4.3.0)

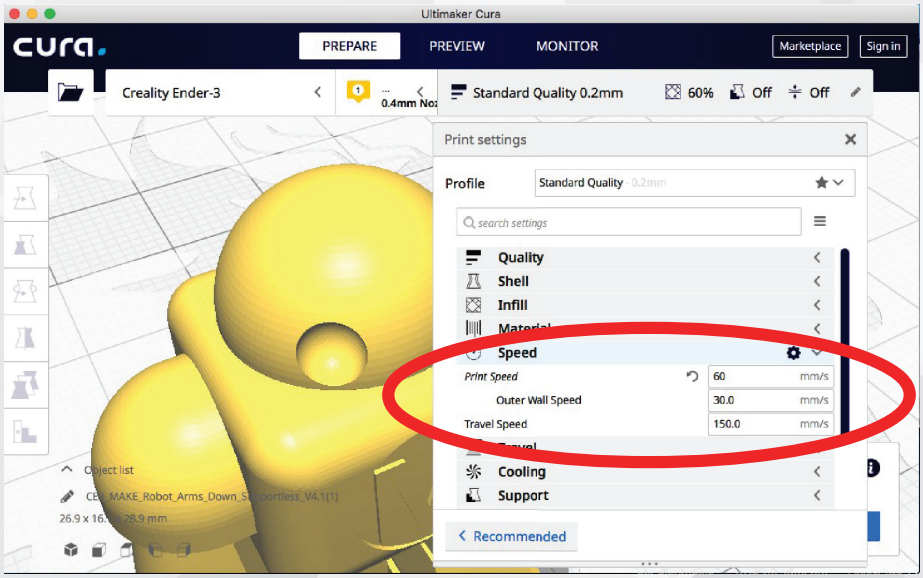
The next menu is "Speed" and allows you to set the print speed. As done for the "Shell" menu, it is advisable to click on the gear icon (red arrow in the figure) and flag the items:

- Print speed
- Outer wall speed
- Travel speed



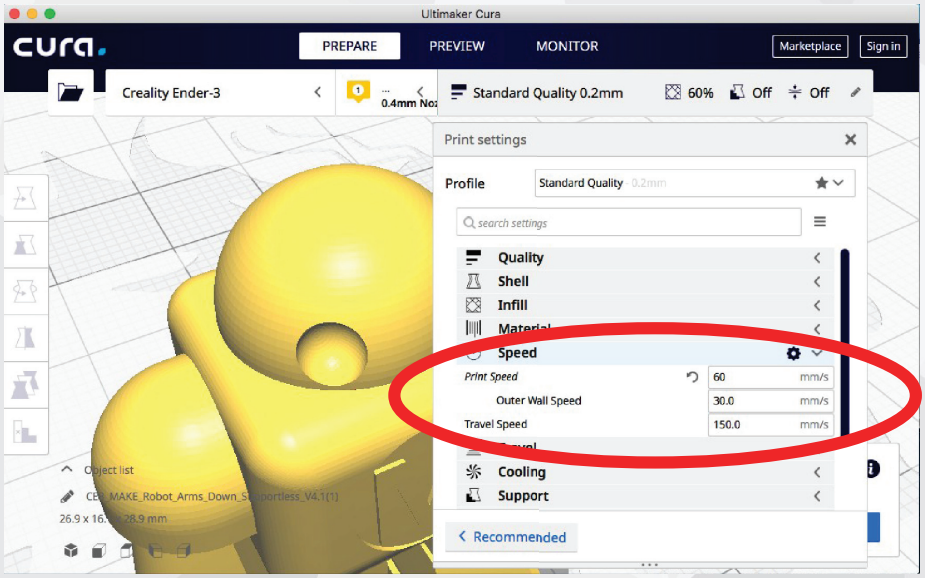
Slicing with Ultimaker Cura(4.3.0)

There are several parameters related to print speed because the Slicing software sets different speeds for walls, infills, travels etc.
The speeds that will not be explicitly set by the user, will be calculated by the software based on general rules to obtain optimal prints without wasting time.



Slicing with Ultimaker Cura(4.3.0)

Here we choose to manually set the three speeds circled in red also to highlight how they are different from each other.
The first of them, "Print speed", is the reference value that the software needs to calculate all the speeds in the various phases, except for the other two that we will set manually.



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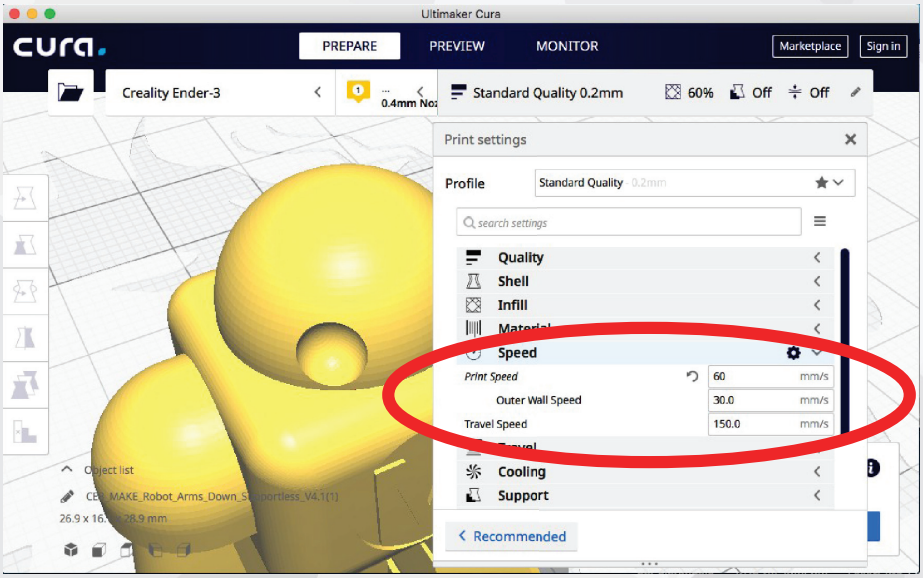
Slicing with Ultimaker Cura(4.3.0)

For most printers, a general speed of 50mm/s, as shown in the image, is a good compromise between quality and printing time. It should always be kept in mind that as the value increases, any defects in the printing will increase.



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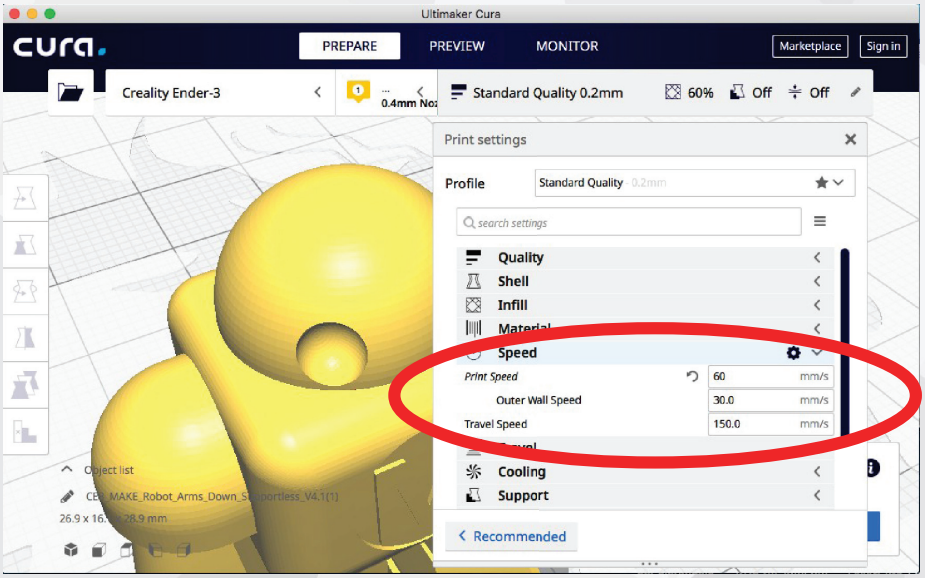
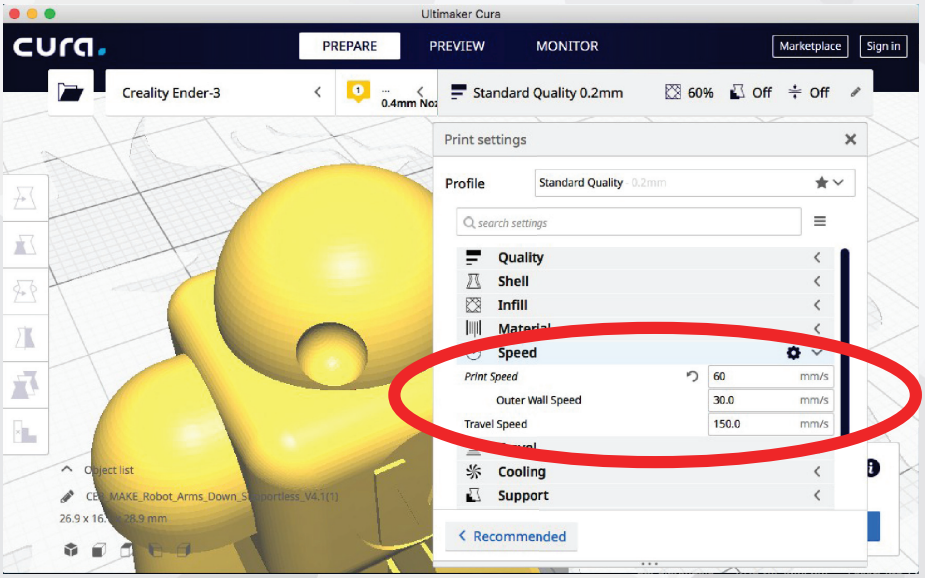
Slicing with Ultimaker Cura(4.3.0)

Since these defects are evident if they are on the outer surface of the print, usually the "Print speed of the external wall" parameter is to be set as about half of the general printing speed: in fact we see "outer wall speeed" in the figure = 25mm/s with a general "Print speed" of 50mm/s



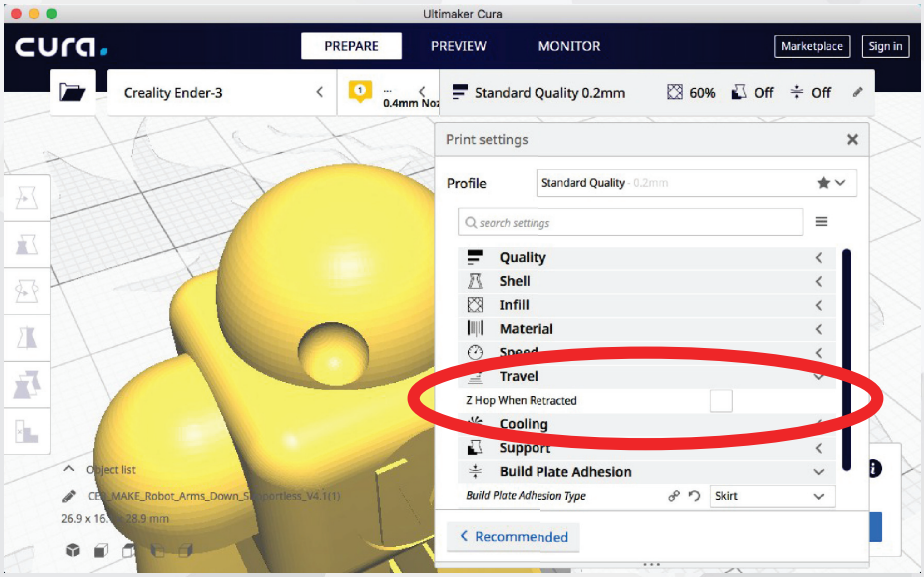
Slicing with Ultimaker Cura(4.3.0)

Similarly, with regard to the "travel speed", it is possible to specify a speed equal to twice the general "printing speed", with a recommended maximum of 150mm / s.



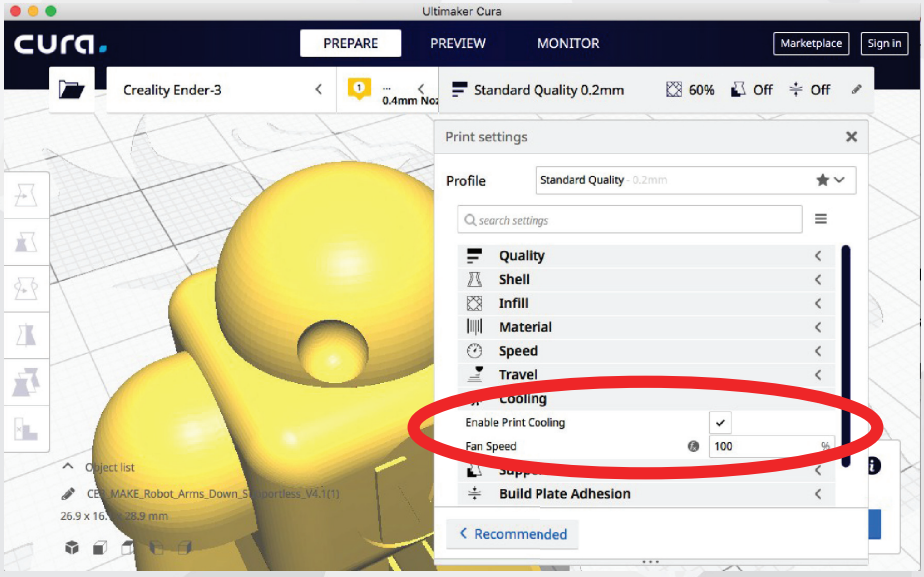
Slicing with Ultimaker Cura(4.3.0)

In the next menu, "Travel", we will find the item "Z Hop when retracted": activating it we will ensure that the printer moves up the extruder nozzle from the layer being printed to avoid leaving any scratches. This however will effect printing times.



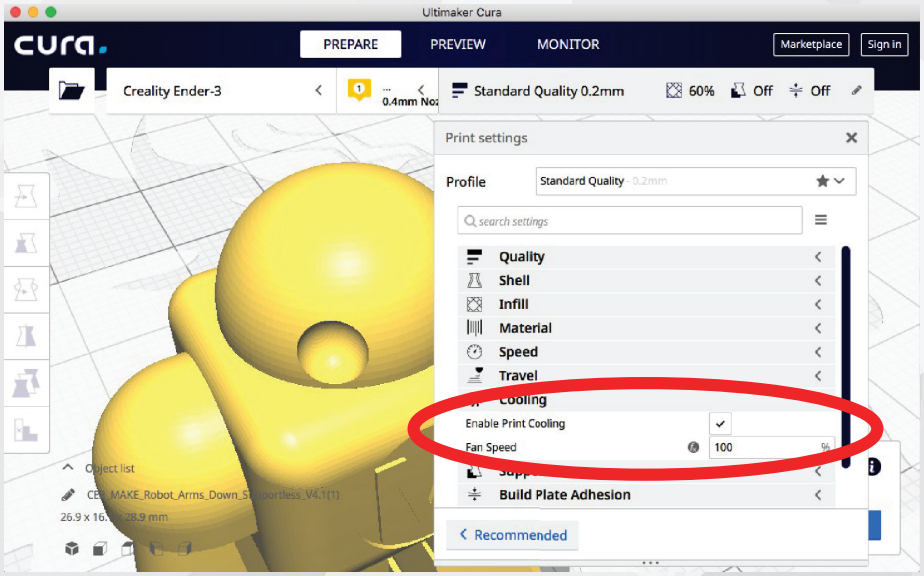
Slicing with Ultimaker Cura(4.3.0)

The next menu is "Cooling" and gives the possibility to activate or not the fan that cools the printed part during printing and to adjust the speed of the fan itself. Active cooling generates prints with better details. If we want very strong prints and don't care aesthetics, we can deactivate cooling.



Slicing with Ultimaker Cura(4.3.0)

The software, automatically, activates the cooling after the second layer, in order to guarantee that the first layer has an optimal adhesion to the printing bed. With tricky materials, such as ABS or Nylon, it may be necessary to deactivate the cooling or reduce the fan speed.



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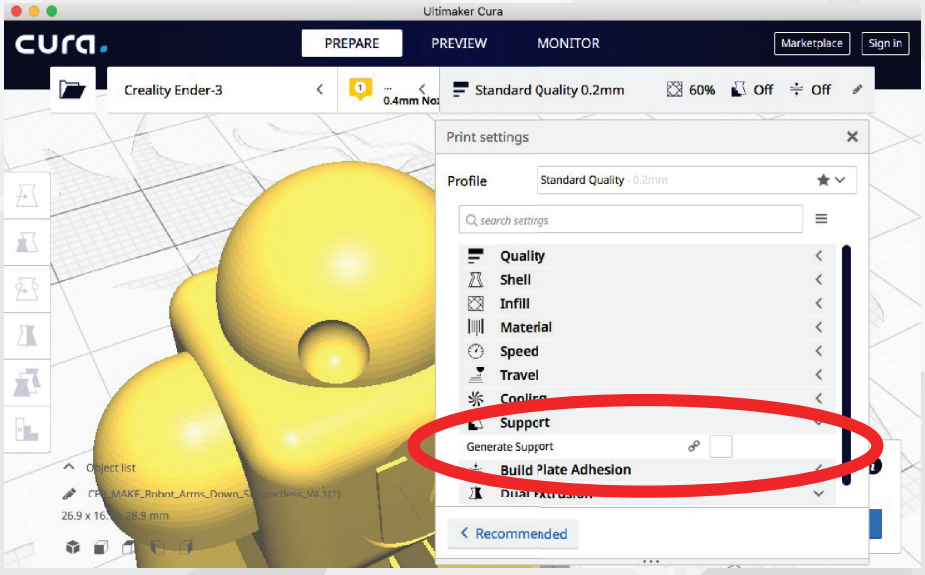
Slicing with Ultimaker Cura(4.3.0)

The next menu, "Support", allows you to enable and manage the parameters relating to the generation of printing supports: these, when they are generated, constitute support structures for all those parts of the 3D model that would otherwise collapse, due to gravity, on the printing bed or on other parts of the model.



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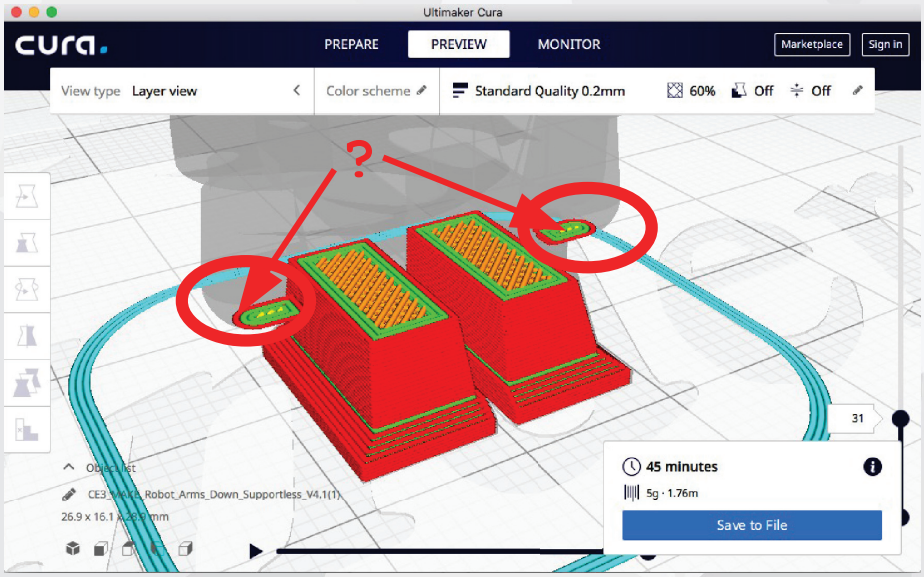
Slicing with Ultimaker Cura(4.3.0)

To better understand the importance of the supports, let's look at the areas circled and indicated by the arrows in the figure: what happens when the printer extrudes the material to generate those areas? Without an underlying support, the molten material would run down, at least until it remains fluid.



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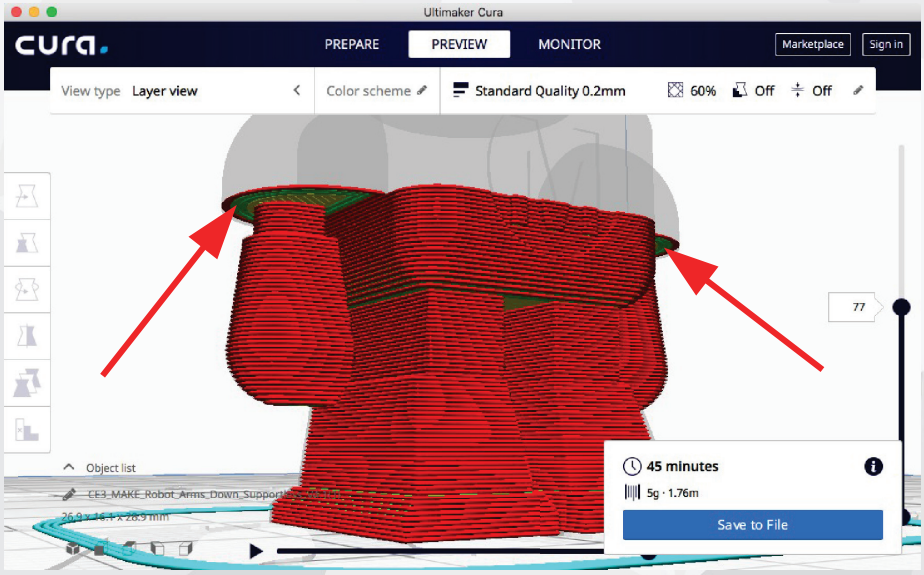
Slicing with Ultimaker Cura(4.3.0)

This problem will occur in all areas that are "overhang", whether they are disconnected from the rest of the model (previous image), or partially connected to it (areas marked by the arrows in the image opposite).



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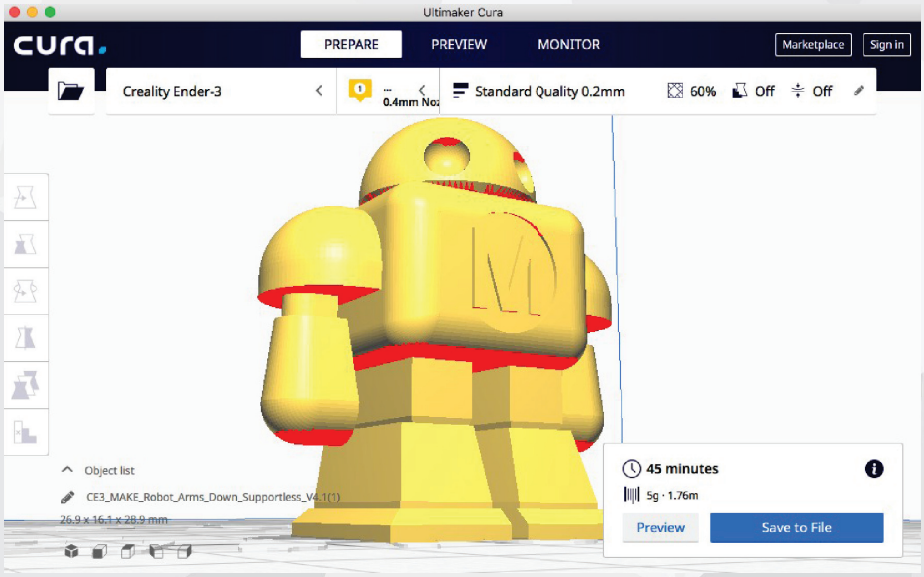
Slicing with Ultimaker Cura(4.3.0)

The areas (overhangs) that can request supports are recognized by the slicing software automatically. Cura, for example, highlights them in the model by coloring them in red, as can be seen in the image next here



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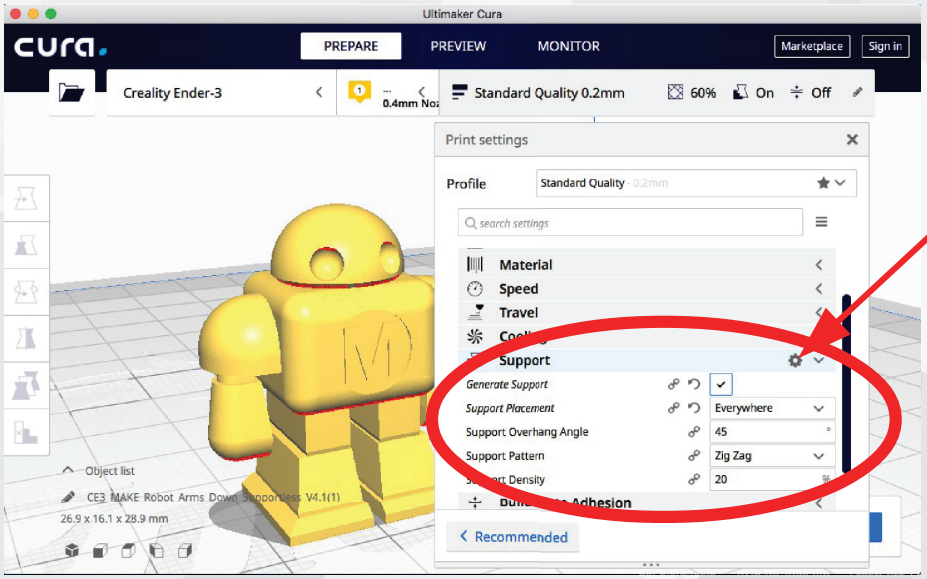
Slicing with Ultimaker Cura(4.3.0)

if we activate the generation of the support, in the menu appear a series of parameters. To view the ones visible in the image next here, you may need to make them explicit by always using the usual gear shaped icon.



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Slicing with Ultimaker Cura(4.3.0)

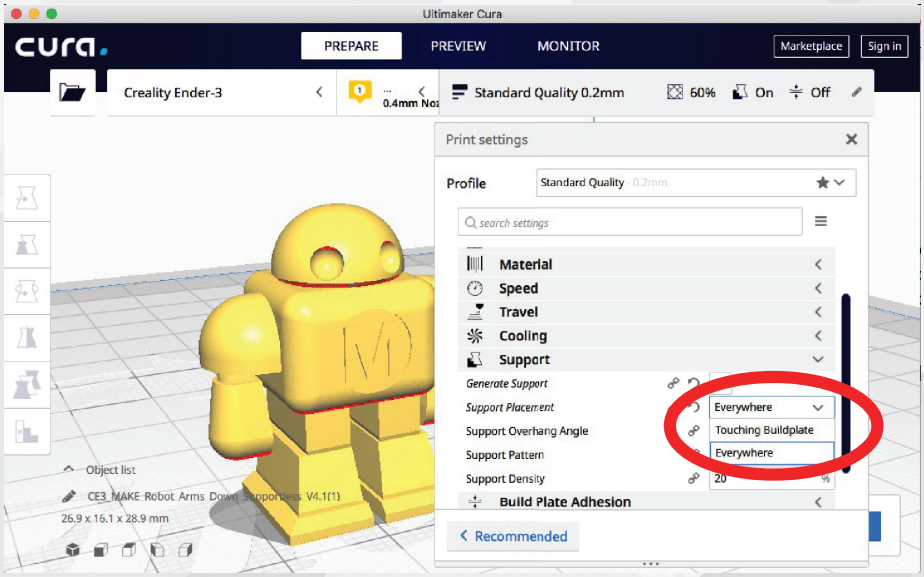
The first item that appears, after the support flag is "Support placement" and gives us 2 possibilities:

Touching Buildplate

Or

Everywhere

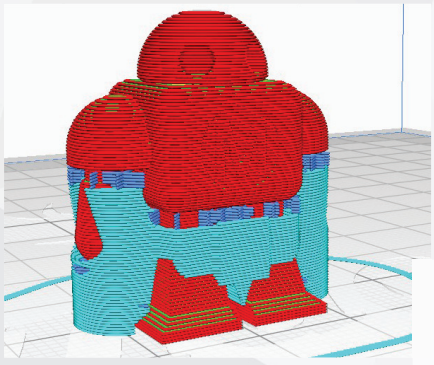
If we choose the first possibility, the software will generate the supports only where they will start from the printing bed...



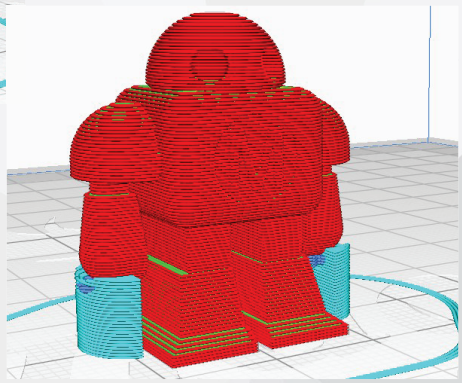
FAB LAB PALERMO

Slicing with Ultimaker Cura(4.3.0)

... while in the second case the software will generate the supports in all the areas that need them.
To understand the difference, just look at the two possibilities in the images next here:
The blue structures are the supports that will be created and must be manually removed at the end of the print.



Supports everywhere



Supports just touching the buildplate

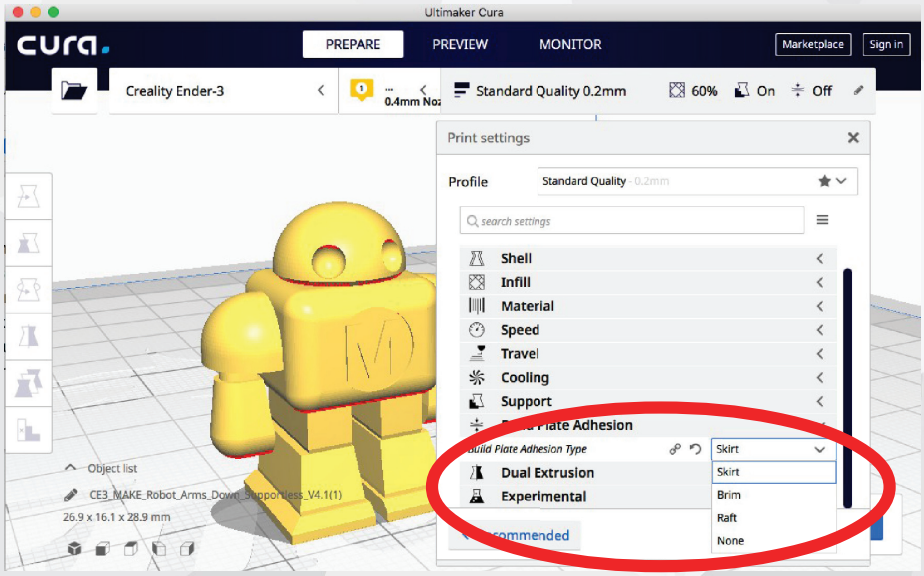
FAB LAB PALERMO

Slicing with Ultimaker Cura(4.3.0)

The next menu is "Build plate adhesion”" and allows you to choose between 4 possibilities:

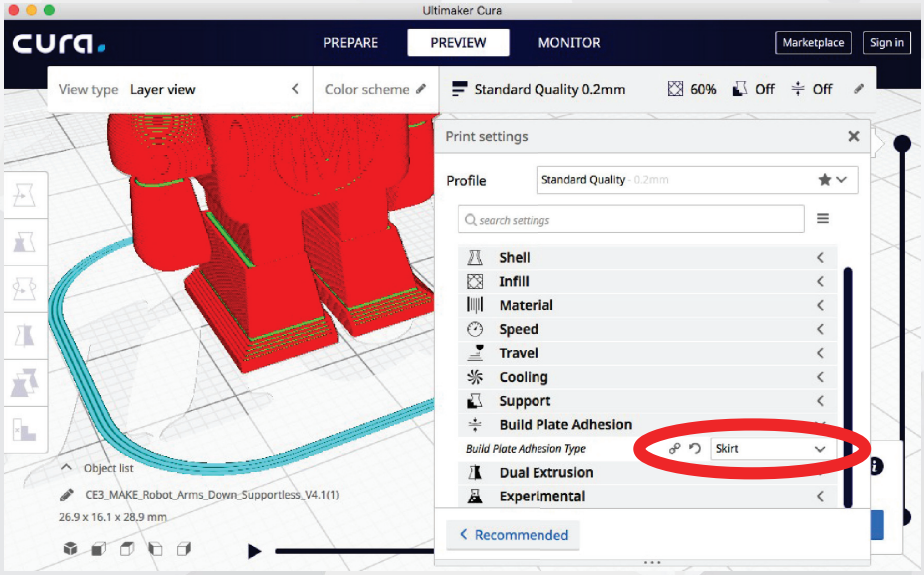
- Skirt
- Brim
- Raft
- None

These are 4 ways to tackle the first layers of printing that influence the adhesion to the bed. The "none" entry expects to begin the first layer of the model without precautions.



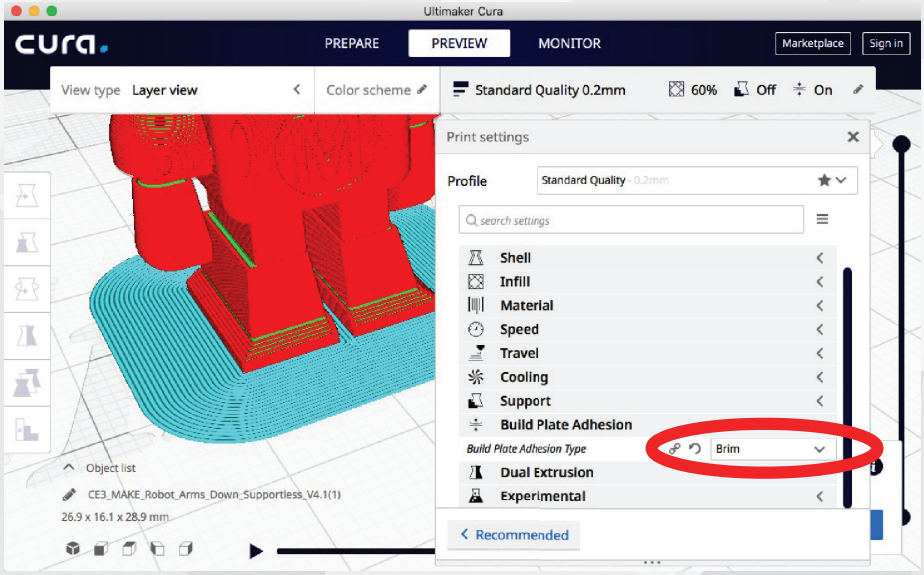
Slicing with Ultimaker Cura(4.3.0)

If we select "Skirt", the printer will extrude one or more lines detached from the model itself. These lines, which will be printed before the model, do not improve adhesion but allow a purge of material and an immediate visualization of any adhesion problems



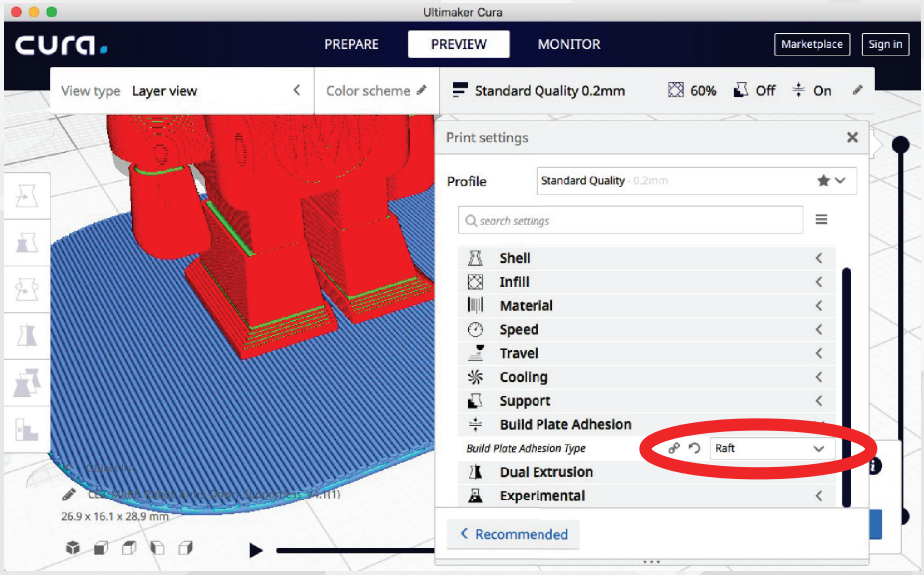
Slicing with Ultimaker Cura(4.3.0)

If we select "Brim", the printer will extrude an expansion surface of the base, obtaining an optimal adhesion, very recommended for models taller than wider. This surface will be manually removed after printing.



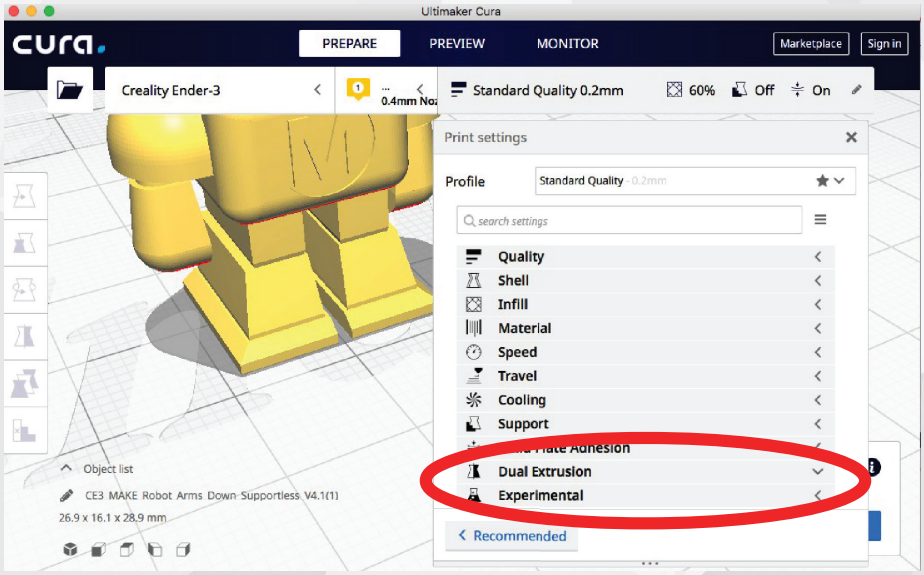
Slicing with Ultimaker Cura(4.3.0)

If we select "Raft", the software will create a platform of material under the model.
This base can be useful when there are particular problems of adhesion, especially on cold building plates.
It will cause a considerable increase in printing times.



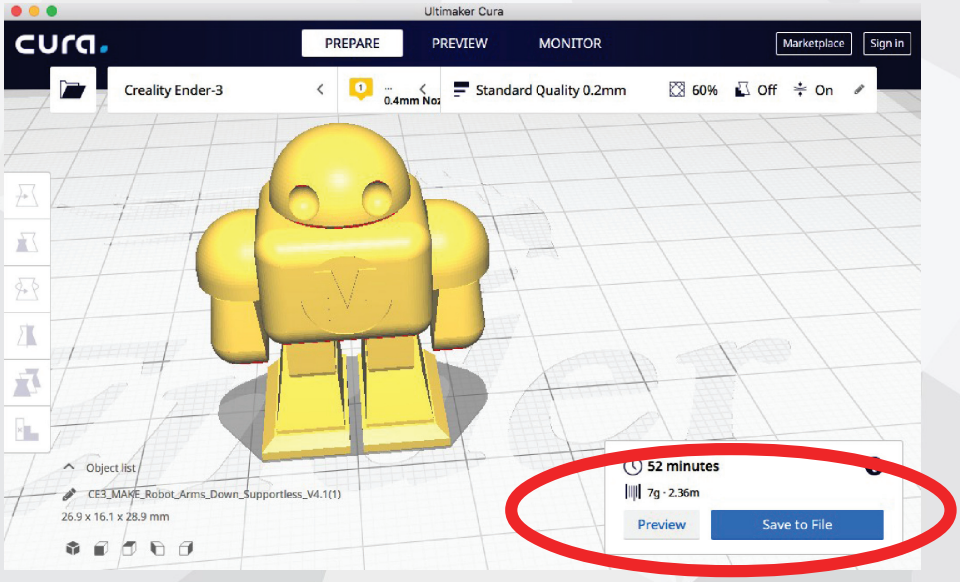
Slicing with Ultimaker Cura(4.3.0)

Any additional menus such as "Dual Extrusion" or "Experimental" are beyond the aim of this course.



Slicing with Ultimaker Cura(4.3.0)

Once all the desired parameters have been set and the "sliicing" has been performed, the file can be saved by clicking on "save file" in the lower right window, where we can also find an evaluation of the expected print time and the quantity of material that will be used.
The file saved this way will be a g-code, readable by the printer.



Part 3. Augmented Reality using Mobile Devices

Augmented Reality

AR Technology in Educational Contexts

HP Reval

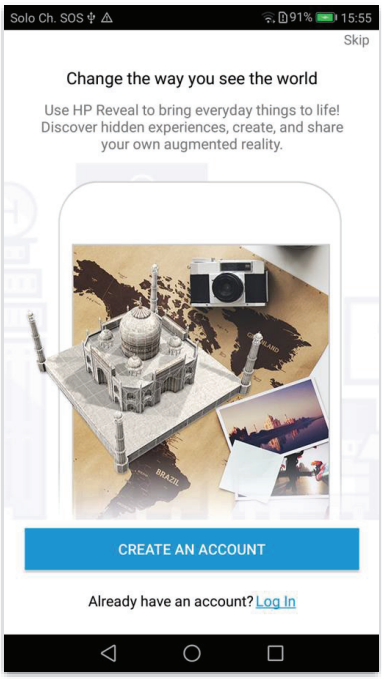
HP Reveal

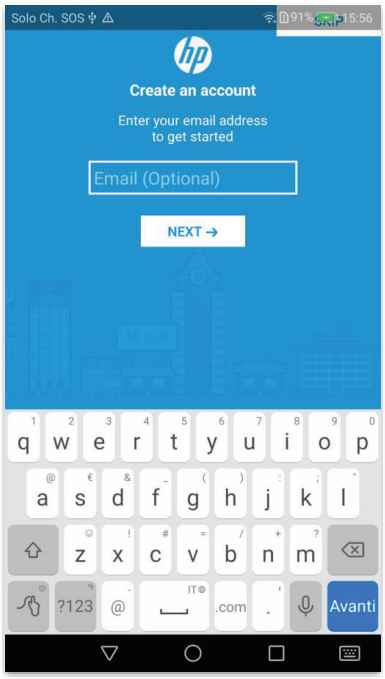
HP Reveal allows teachers or students to create or view augmented reality (AR) experiences that blend the physical and digital using a mobile device's camera

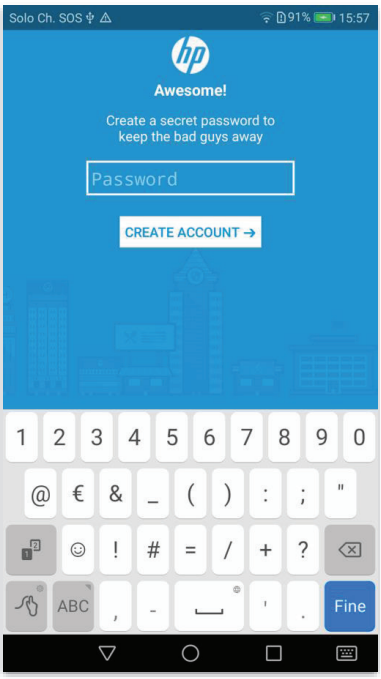
REVEAL

HP Reveal

1. Install and Create an HP Reveal account.



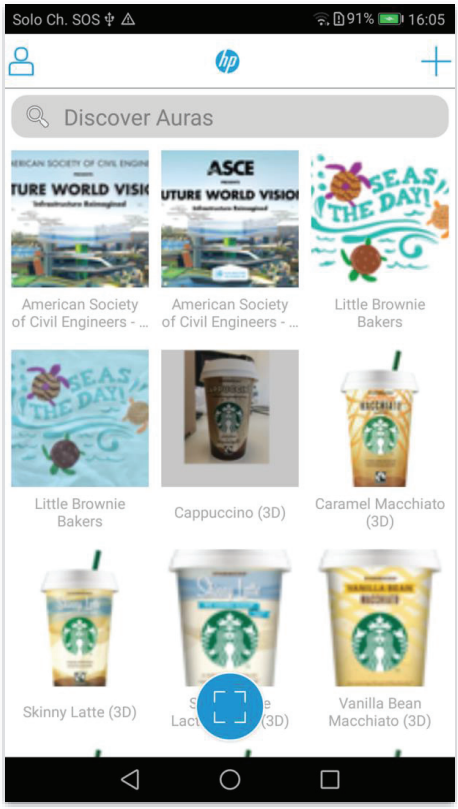




HP Reveal

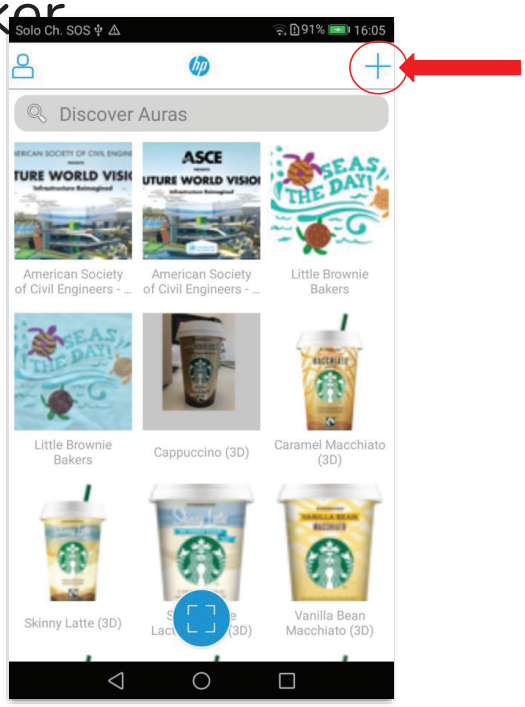
2. Check your e-mail and Log in to your account.

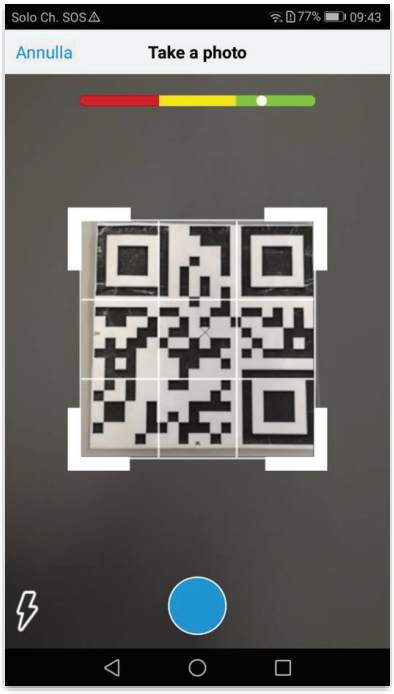
The elements displayed are called **Auras**. An auras is just an experience you create within HP Reveal.



HP Reveal

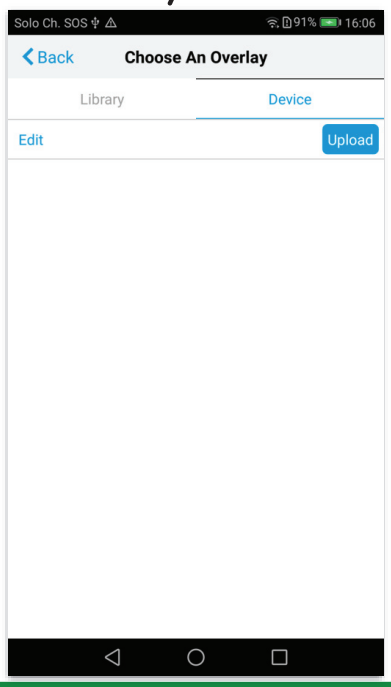
3. Start creating your Auras: upload you marker

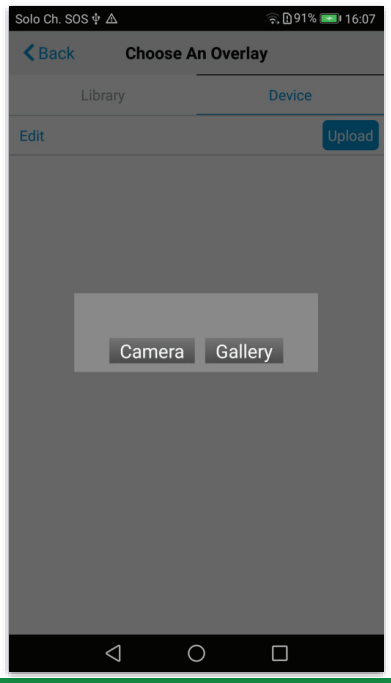


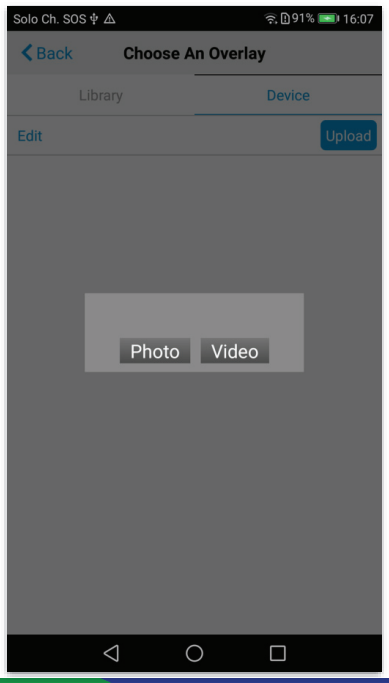


HP Reveal

3. Start creating your Auras: upload your overlay

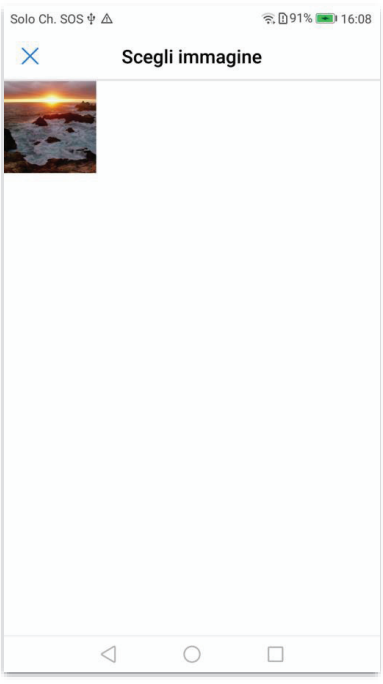


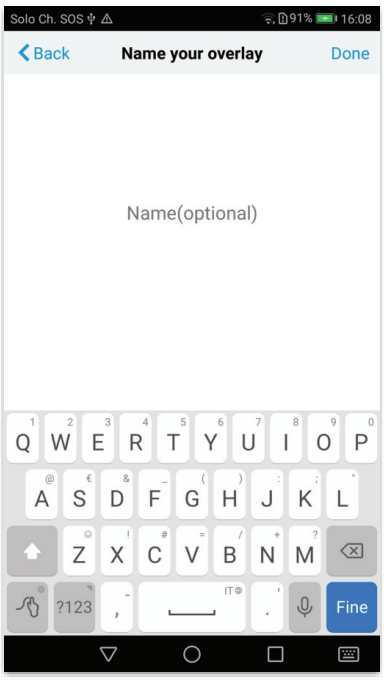




HP Reveal

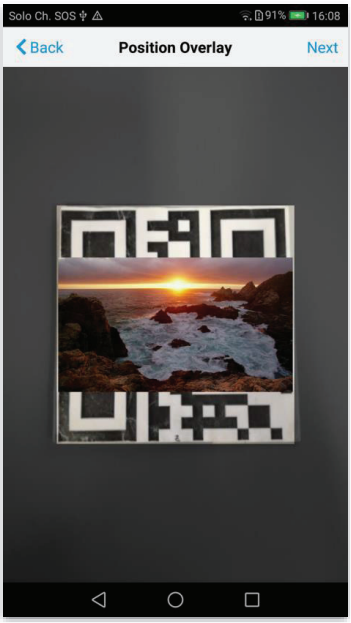
3. Start creating your Auras: upload your overlay

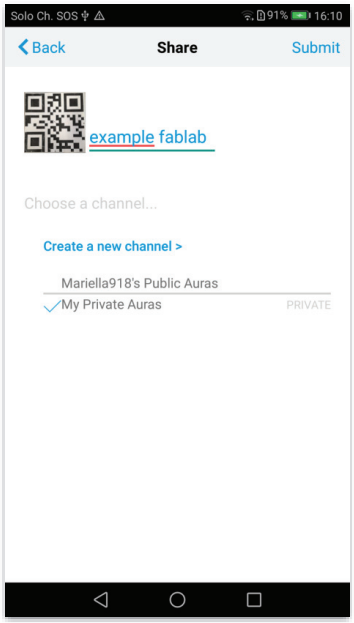




HP Reveal

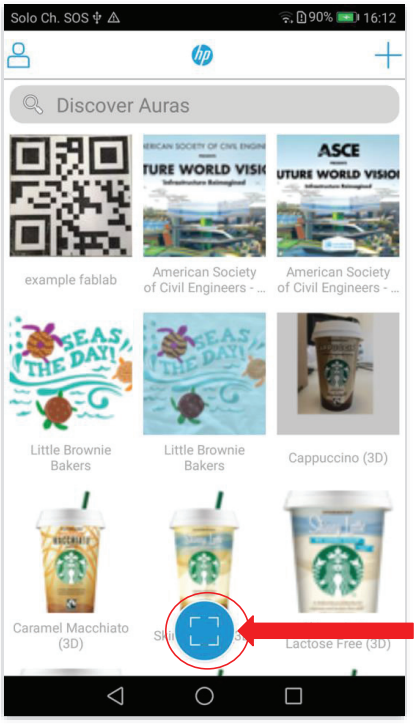
3. Start creating your Auras: you can preview the aura. And if you're satisfied, you save it.





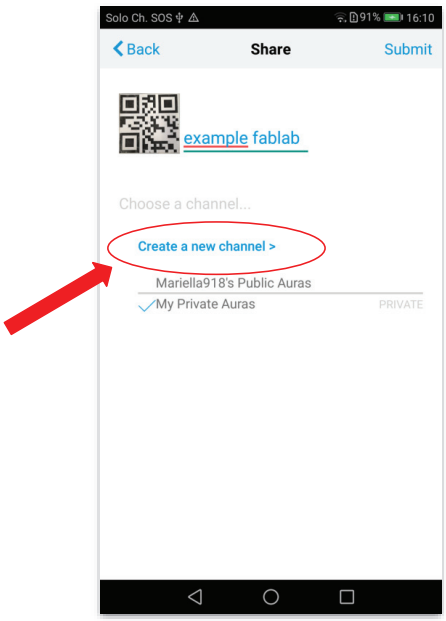
HP Reveal

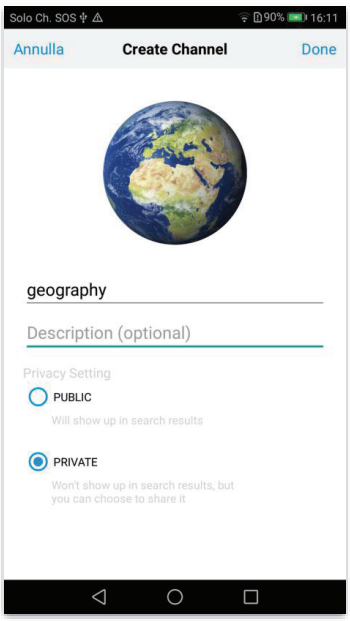
4. Launch the Aura

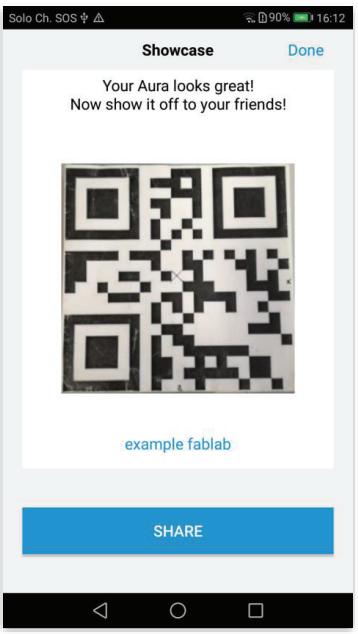


HP Reveal

If you want to create a Channel you need to do this at the ‘share’ stage of the Aura creation process.







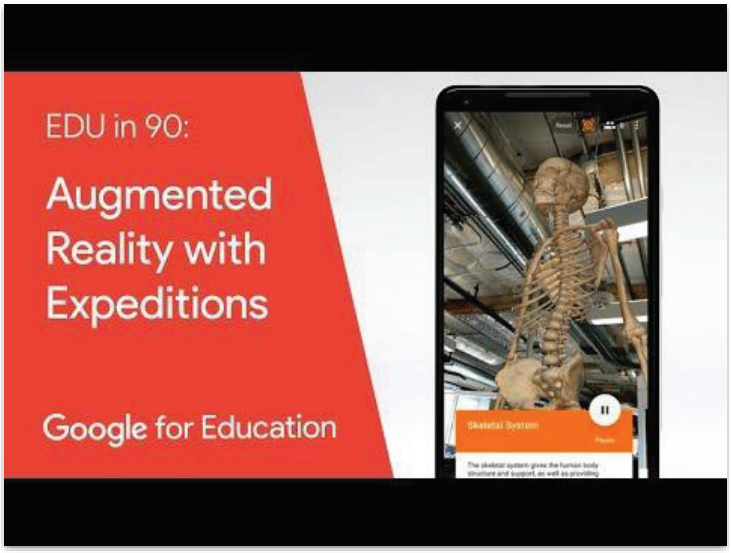
HP Reveal

You can directly share a link to your Private content meaning it can be viewed by others but only if they have the link.

Google Expedition

Google Expedition

Google Expeditions is an immersive learning and teaching tool that lets you go on VR trips or explore AR objects.



➢ https://edu.google.com/products/vr-ar/expeditions/?modal_active=none

Google Expedition

- Minimal setup for maximum engagement
- Unique experiences within reach
- Hundreds of adventures for the classroom
- Inspiring students' creativity and imagination

➢ https://edu.google.com/products/vr-ar/expeditions/?modal_active=none

Google Expedition

What you need to Experience AR:

- Expeditions app
- Mobile device that supports ARCore (Android) or ARKit (iOS)
- Optional: Selfie stick

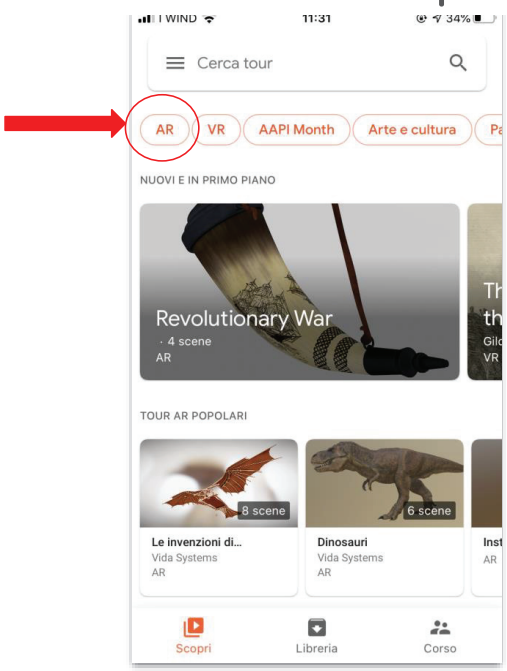
➢ https://edu.google.com/products/vr-ar/expeditions/?modal_active=none

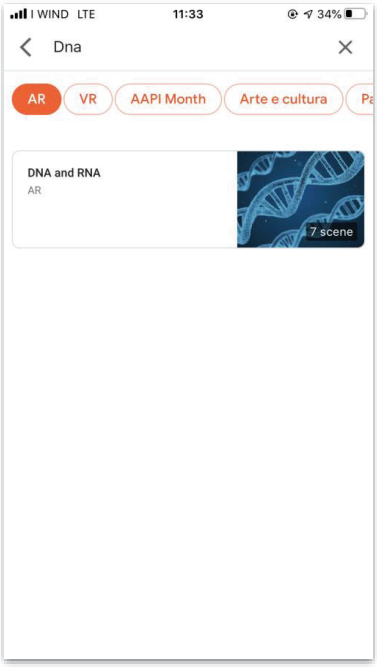
Google Expedition

➢ https://edu.google.com/products/vr-ar/expeditions/?modal_active=none

Google Expedition

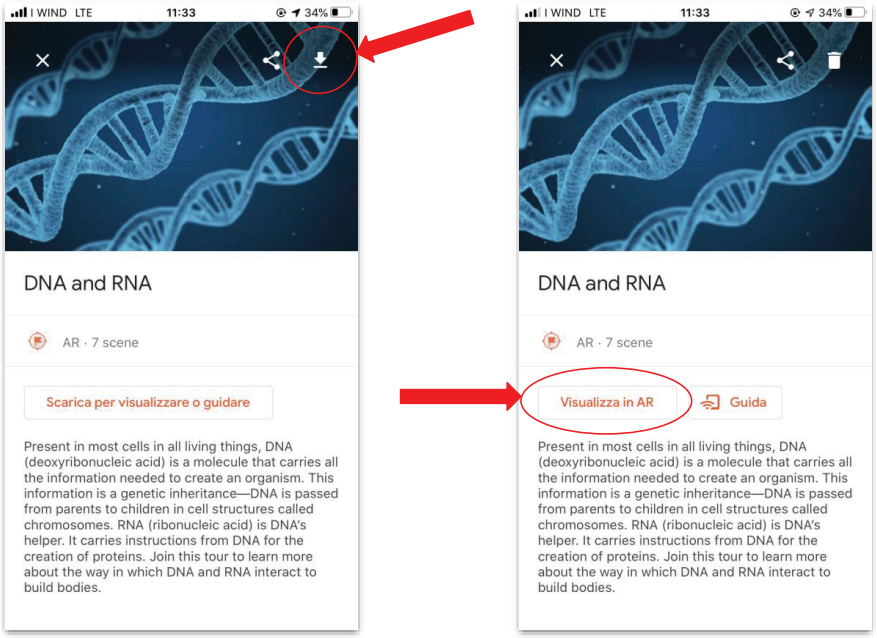
Open up Expedition app, click on AR and type the educational topic





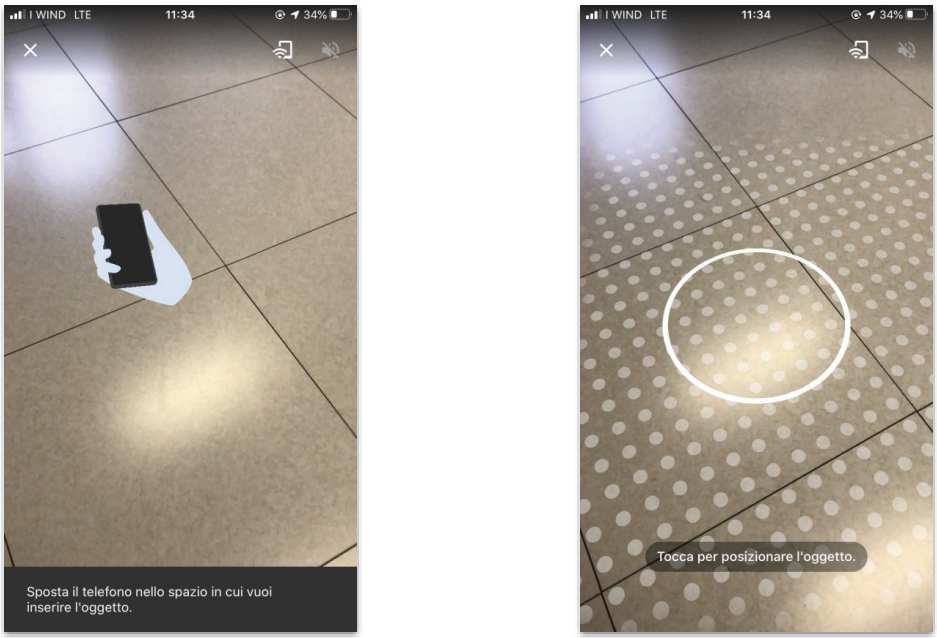
Google Expedition

Open up the element, download it and start AR visualization



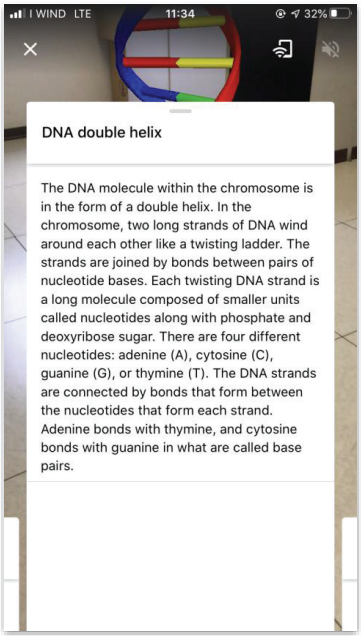
Google Expedition

Scan the surface where you want visualize the AR element

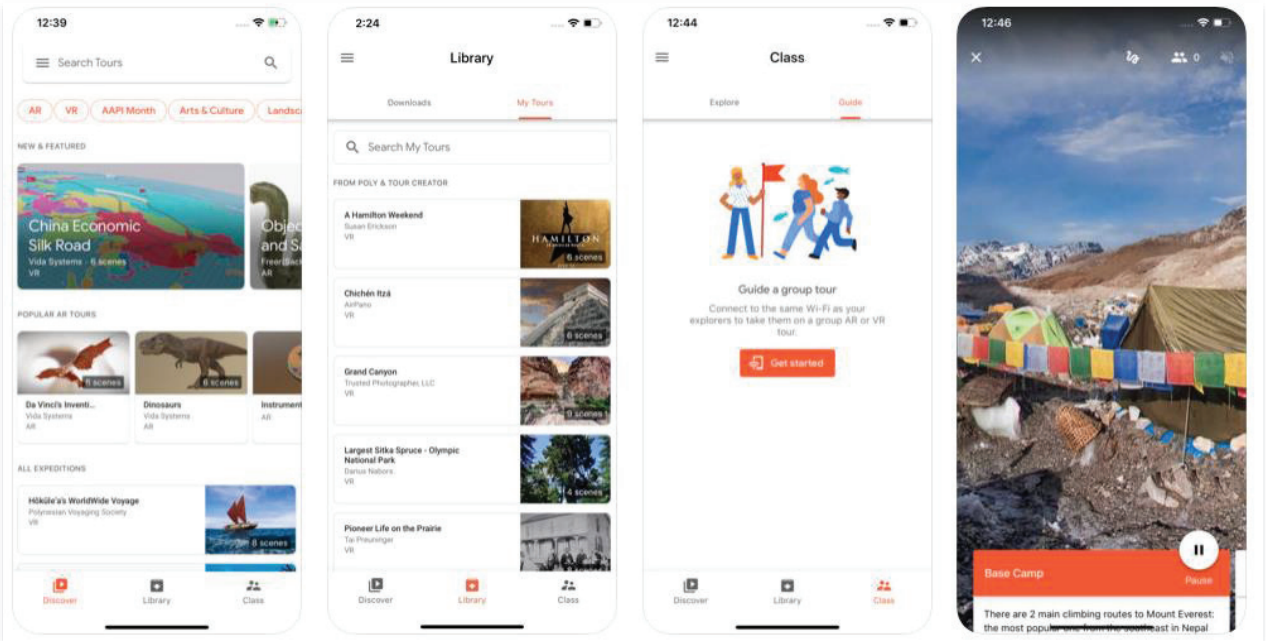


Google Expedition

Touch to position the object

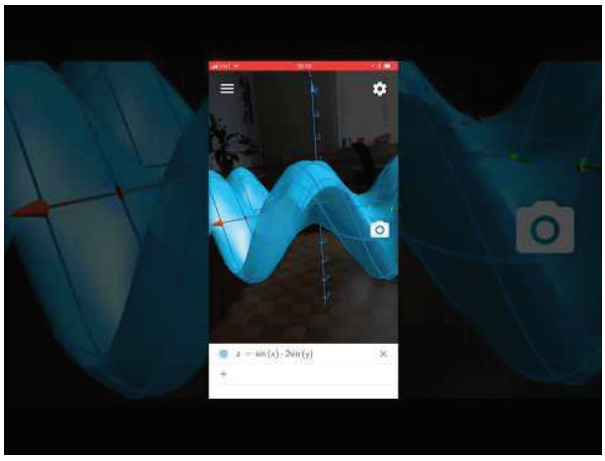


Google Expedition



GeoGebra
Augmented Reality

GeoGebra Augmented Reality



Place math objects on any surface, walk around them, and take screenshots from different angles. This app includes several examples of 3D math objects that you can place on your table, floor or any flat surface around you.

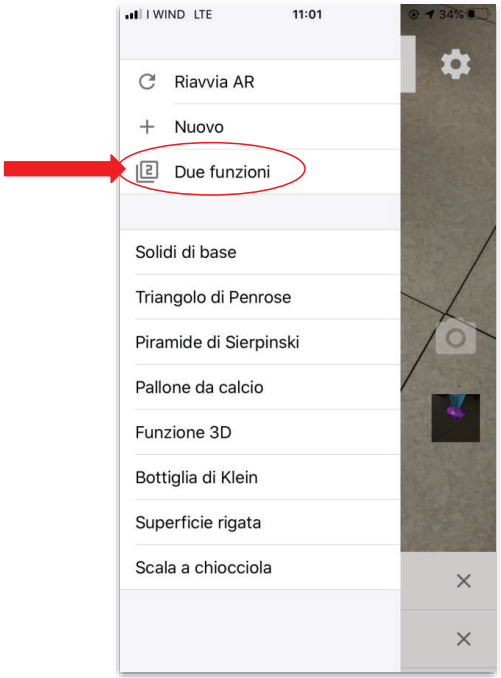
➢ https://www.geogebra.org/m/RKYFdQJy

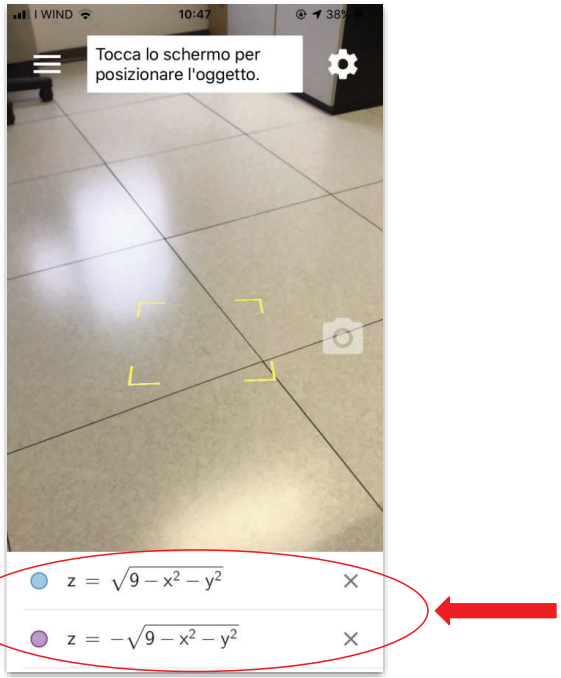
GeoGebra Augmented Reality

1. Open up GeoGebra Augmented Reality app on iPad or iPhone.

GeoGebra Augmented Reality

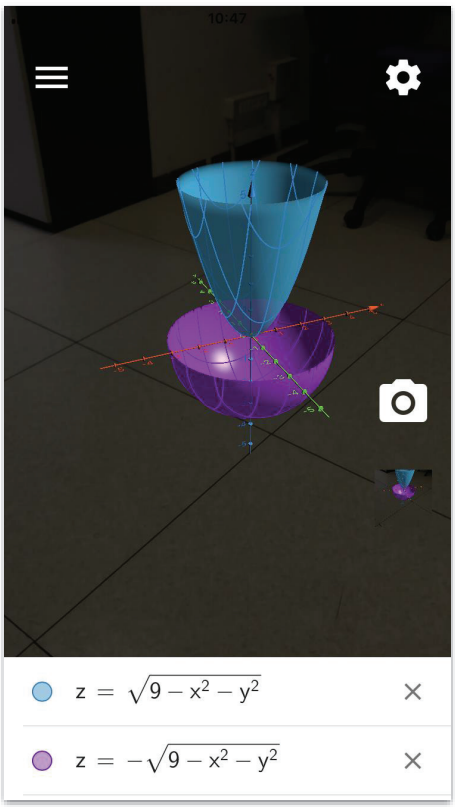
2. Go to Menu and select “Two Functions” and type the functions



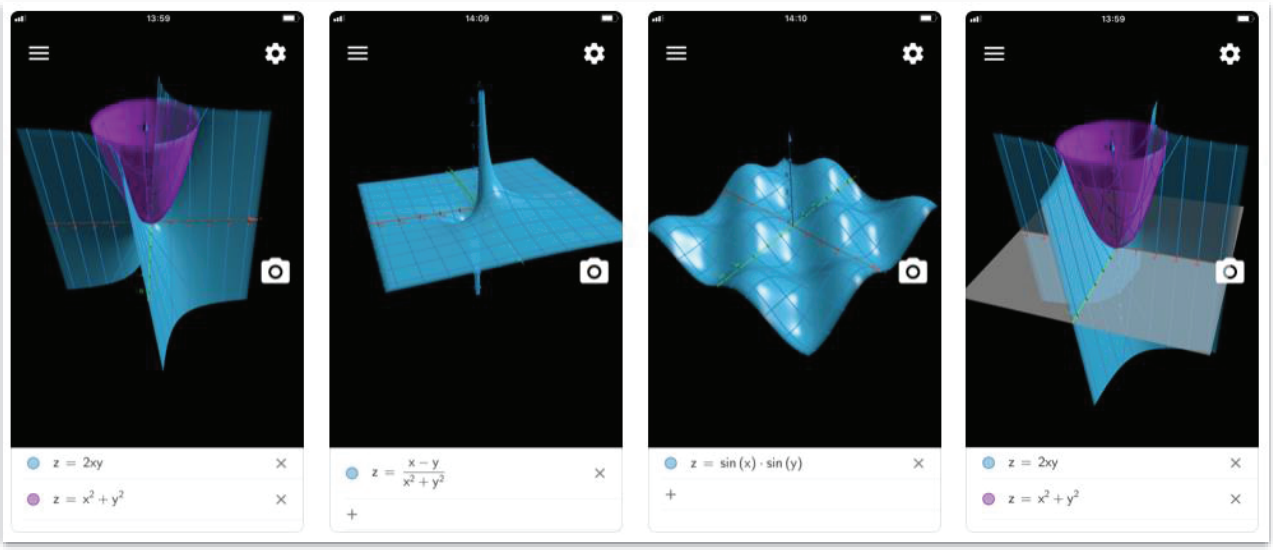


GeoGebra Augmented Reality

3. Touch the screen to position the object on the chosen surface



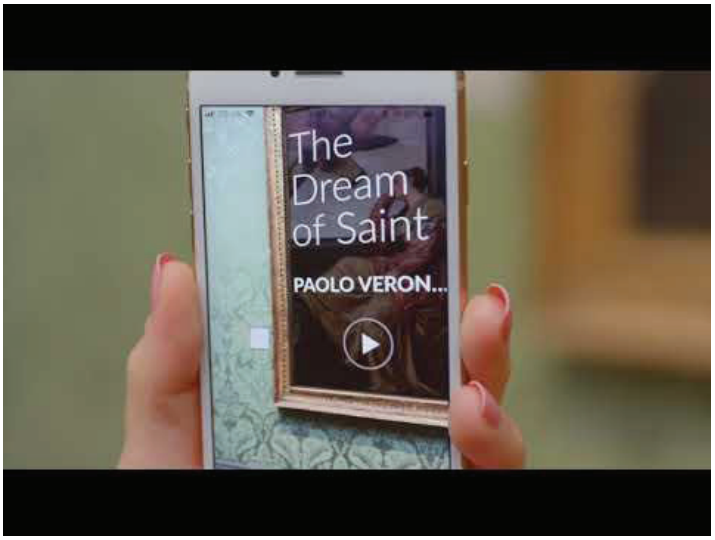
GeoGebra Augmented Reality



Smartify

Smartify

Smartify uses image recognition to identify scanned artworks and provide people with additional information about them.



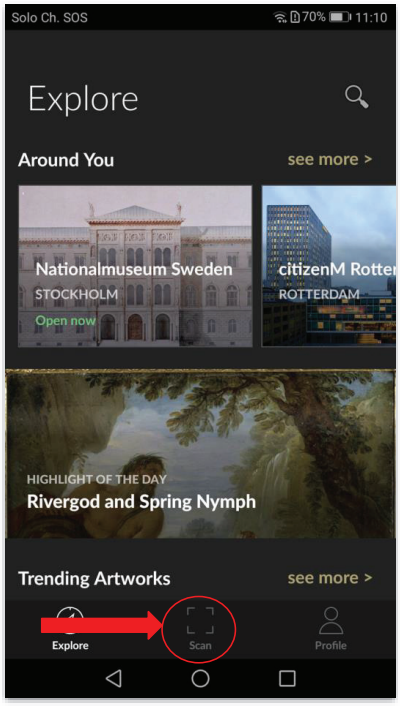
➢ https://smartify.org

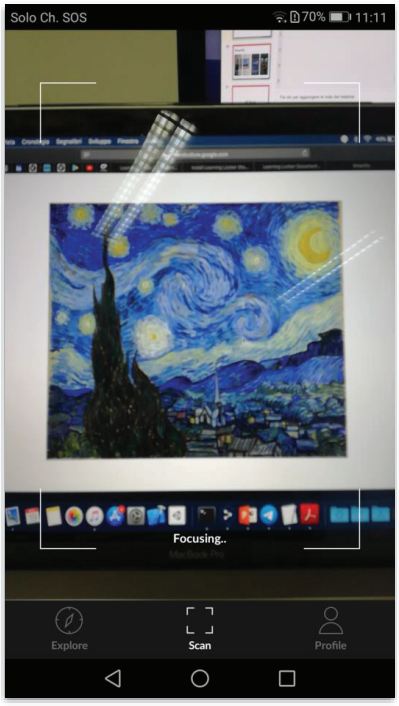
Smartify

The app has simple, elegant and intuitive graphics for the user. Smartify is not only a "recognizer" of works of art, but also serves as a database as it allows you to store, even chronologically, the works of art visited by creating real art collections.

Smartify

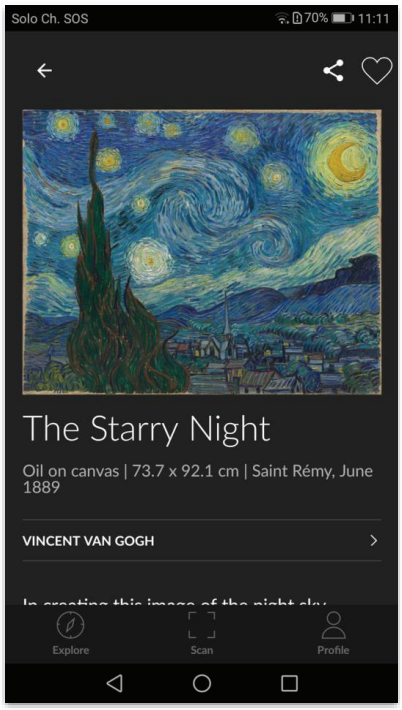
1. Open up Smartify app and scan the art

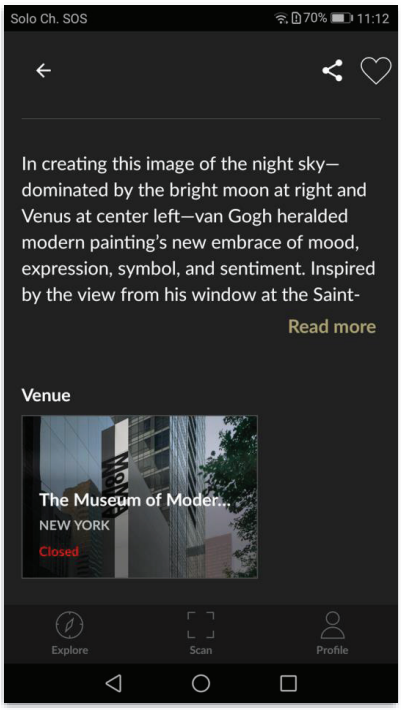




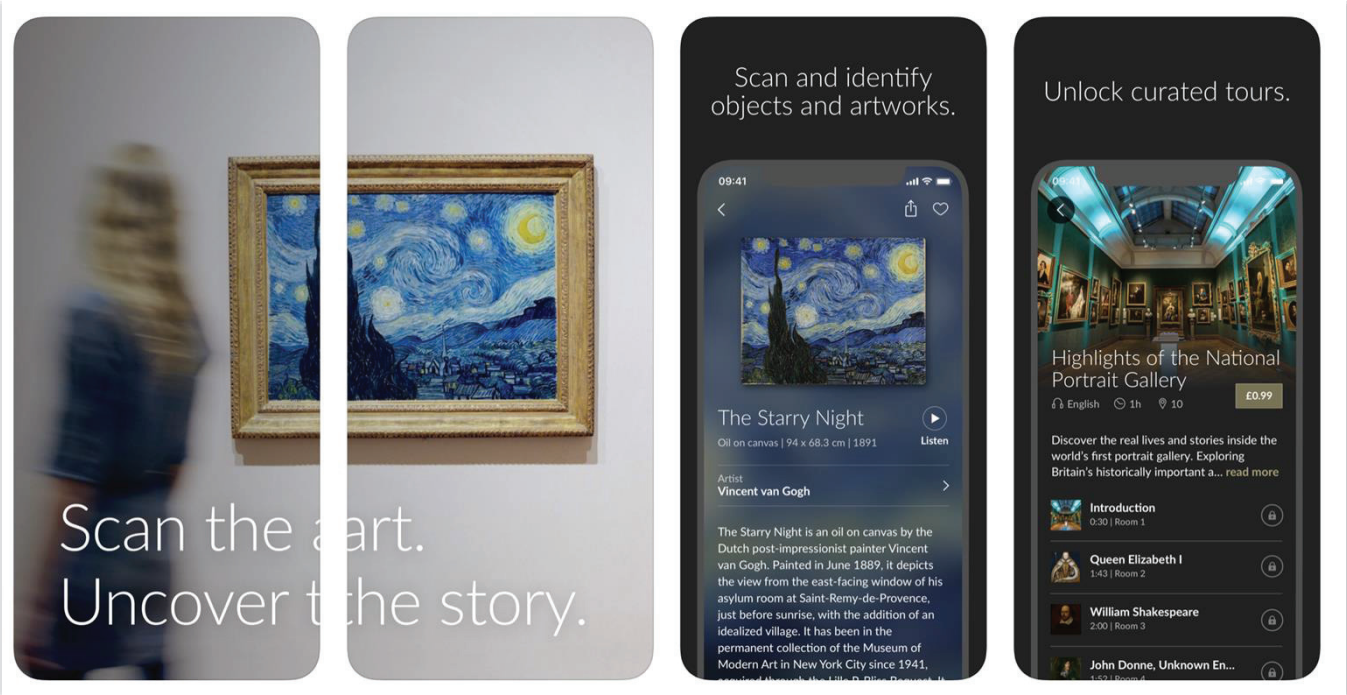
Smartify

2. Uncover the story of art scanned





Smartify



MoleculAR Experience

MoleculAR Experience

MoleculAR is a educational experience, available for iOS.
It's possible to bring the infinitely small into the real dimension, simply thanks to augmented reality and without sophisticated laboratory tools. This software was created by a team of students from the Apple Developer Academy in Naples.

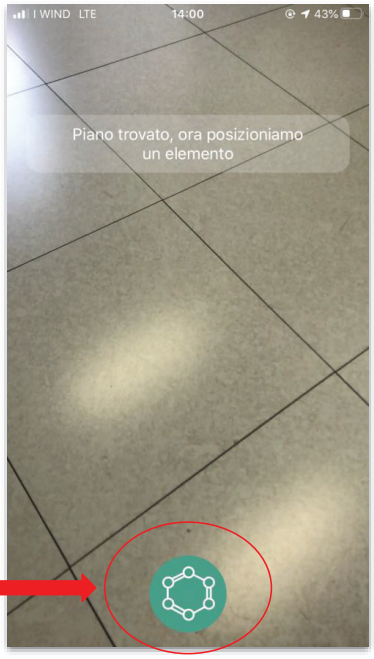
➢ https://apps.apple.com/it/app/molecular-experience/id1352307216

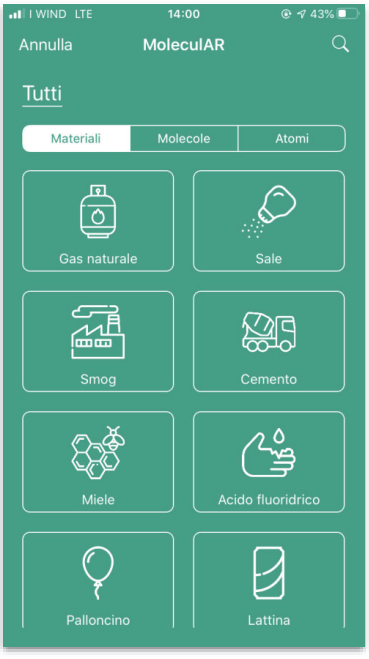
MoleculAR Experience

The use of MoleculAR Experience is very simple. Simply frame a horizontal surface with your iPhone or iPad camera and, when a yellow dial appears on the screen, select one of the chemicals to be displayed. You can observe atoms and particles from any angle, moving your device around the molecules, but also zoom in and out with traditional on-screen gestures that have become universal.

MoleculAR Experience

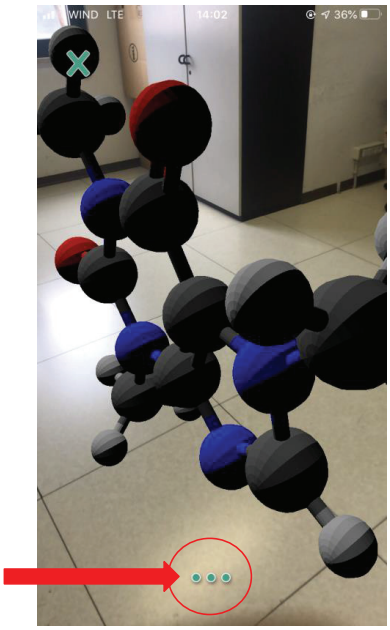
Open up MoleculAR app and select the AR element

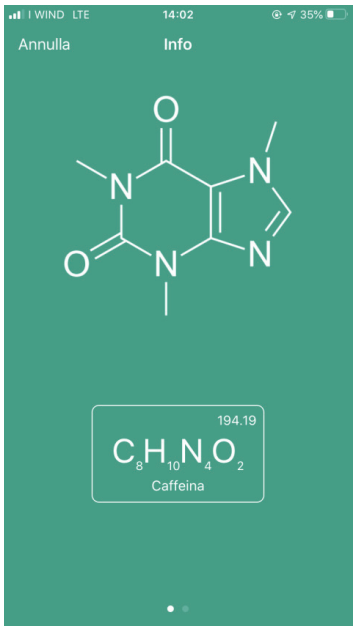




MoleculAR Experience

Scan the surface and tap to visualize the element





MoleculAR Experience

Human Anatomy 4D-Mixed Reality

Human Anatomy 4D-Mixed Reality

Anatomy 4D is a free app that uses augmented reality to let students interact with the human body.

➢ https://apps.apple.com/us/app/human-anatomy-4d-mixed-reality/id1381050423

Human Anatomy 4D-Mixed Reality

Irusu Human Anatomy 4D brings Human Anatomy right in front of eyes with the power of iOS devices ARKIT, where kids, teachers, medical professionals, students and anyone who wants to learn interactively about human anatomy and its body layers can use this free to use application.

➢ https://apps.apple.com/us/app/human-anatomy-4d-mixed-reality/id1381050423

Human Anatomy 4D-Mixed Reality

CoSpaces Edu

CoSpaces Edu

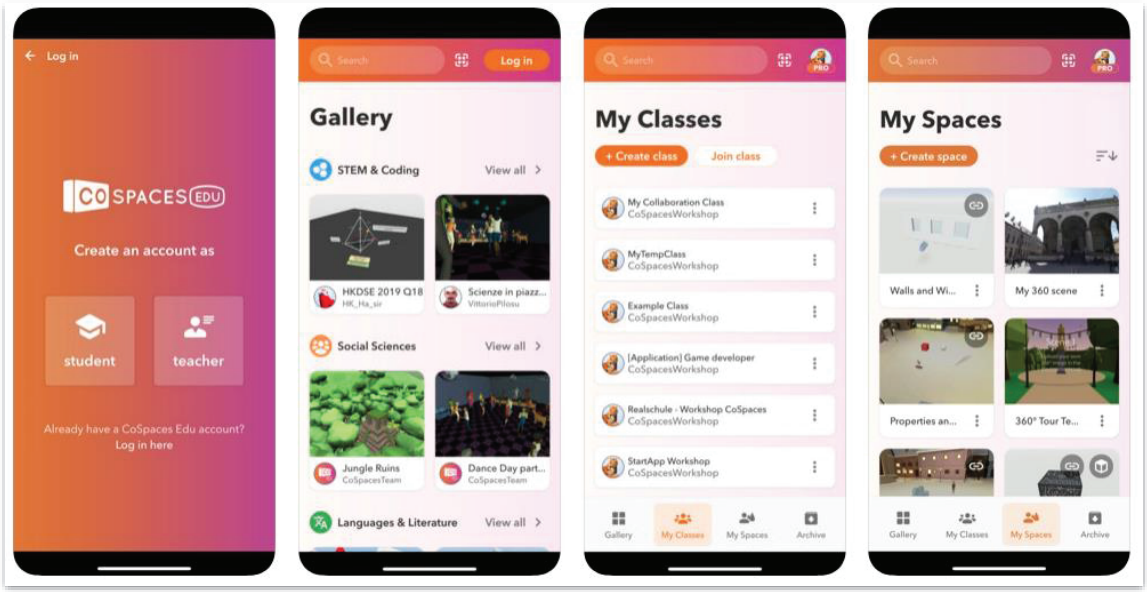
CoSpaces Edu is an intuitive educational technology enabling students and teachers to easily build their own 3D creations, animate them with code and explore them in Virtual or Augmented Reality.

- https://cospaces.io/edu/CoSpacesEdu-Marketing-Brochure.pdf
- https://www.youtube.com/channel/UC6VsnmaKQ9MNRpJbFsIhoGw
- https://cospaces.io/edu/CoSpaces-Edu-Pro-Guide.pdf

CoSpaces Edu

The goals of CoSpace are to make students future-ready with 21st Century skills and the 4 C's

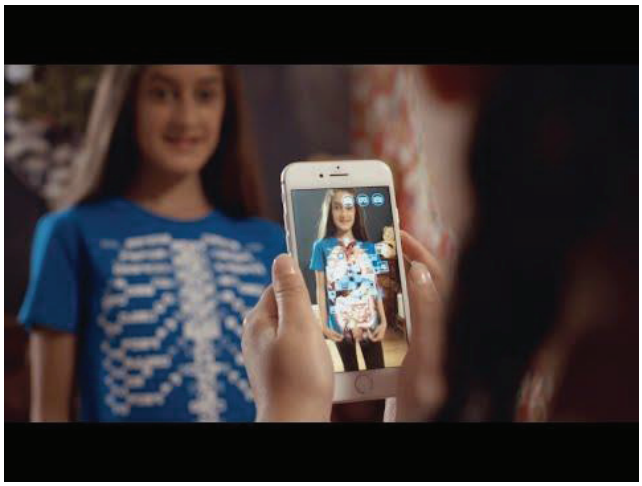
CoSpaces Edu



Curiscope

Curiscope

This AR app aims to provide a detailed look into the human body. Curiscope AR system is distributed with a special t-shirt that has anchor points. They help the device to scale the simulation properly. it's possible to easily view the circulatory system, skeleton, muscles, and internal organs.



➢ https://www.curiscope.com

Curiscope

In the below link there are some resources that have been designed by teachers for teachers! They are compatible with US common core, UK national curriculum and the international curriculum. They cover elementary and primary school years, but are super flexible so it's possible to quickly adjust to fit your school.

➢ https://www.curiscope.com/pages/science-lesson-plans-human-body

Curiscope

AR Application Comparison

	HP Reveal	Google Expedition	Geogebra AR	Smartify	MoleculAR Experience	Human Anatomy 4D	CoSpace Edu	Curiscope
Device's Operative System	• Android • iOS	• iOS compatible with ARKit • Android compatible with ARCore	iOS	• iOS • Android	iOS	iOS compatible with ARKit	• iOS • Android	• iOS • Android
Features	Allow to overlay image or video on marker	AR markerless experience	Place math object on any surface	Allow to identify scanned artwork	Place model of atoms or particles on surface	Allow to interact with the human body	Allow to build AR experience	AR marker based experience. The marker is a special t-shirt
Educational topic	Everything	Everything	Math	Art	Chemistry	Human Anatomy	Everything	Human Anatomy

ARLectio

An AR Educational Toolkit

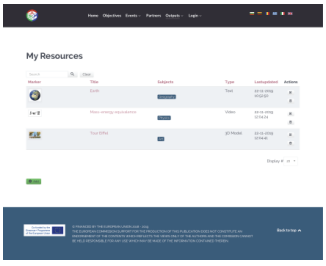
As easy as Possible...

- The main aim of this tool is to provide an easier way to produce and consume AR educational resources.
- Simple user interface.
- Few functions to implement AR educational contents on most media channels (images, video, text and 3D model).

ARLectio architecture

- A **web platform** to manage a class and produce AR educational resources (used by teachers).
- A **mobile app** for iOS and Android to consume the educational resources.

Web platform



- Address:

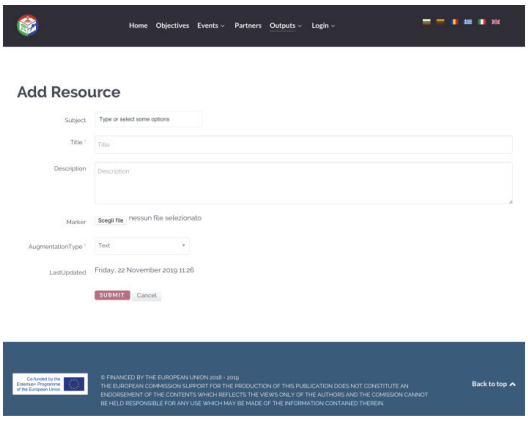
  https://www.fablabschoolnet.eu/en/login.html

- For each school we will setup the classes and register relative teachers.
- Each teacher will provide a list of students to be involved in CSV format (a schema will be provided shortly). Then, we will take care of their registration.

Web platform - Authoring

- Manage the AR educational resources (create, edit, delete and organize).

- The AR resource will have:
  - Subject;
  - Title;
  - Description;
  - Marker (photos, picture, QR code, …);
  - Augmentation Type (*Text , Image, Video, 3D Model*);
  - Augmentation;
  - Last Updated (Automatically added).

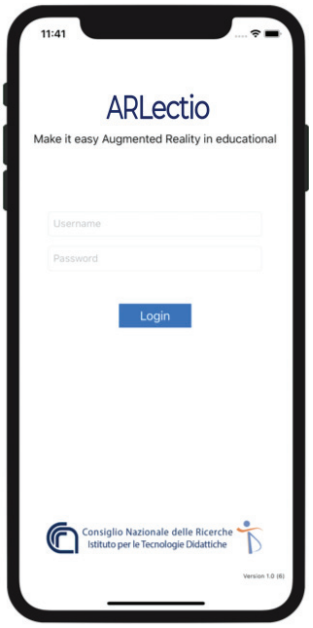


Mobile App

- Soon the app will be available on the market (Google Play store and Apple store) for free.
- Main users are **Students**.
- The user needs an account to use it.

Mobile App

- The students access the educational AR resources created by their teaches.
- Resources are grouped by subjects.
- An interactive visual scanner is available to consume the educational contents associated to markers.



LESSON PLANS - ROBOTICS

Lesson 1: Creating light shows

Description:

The students create light shows changing the brightness and the color of the robot LED's.

Learning Objectives:

- to understand what a loop is
- to be more familiar with the hardware of mbot robotics
- to build and execute iteration structures using robotics

Expected results:

The students will be able to create programs using their computer, connect the robots and run the code. They will recognize the LED's of the robot and create iteration structures changing the brightness and the color of LED's.

Key issues:

programming, robotics, iteration structure

Technologies:

mBot Ranger Robotics

Software:

mBlock

Age of students:

16-18

Number of students

70 (6 classes)

Didactic Hours:

2 per class

Assessment:

The students in each class were divided in 4 teams and used laptops in order to create the code. The students acquired the necessary skills for their autonomous use of the software and the robots. They expressed their satisfaction for the educational material and enjoyed the procedure of creating a light show. Some technical problems were reported about the connection between the laptop and the robot.

YouTube Link:

https://www.youtube.com/watch?v=5QK23iGbUxU

Worksheet for the students

Introduction to the RGB LEDs of mBot Ranger

The 12 RGB LEDs in Me Auriga of mBot Rangers are mounted in a circle. Each RGB LED can be programmed to control the brightness of three colors (red, green and blue) and combine these three colors to produce different colors of light.

How to control the RGB LED with blocks:

The "All" option determines the number of RGB LEDs . The default value of this tab is "all". The "all" option means that we can control all 12 RGB LEDs in Me Auriga . When we select eg "2", it means that we can only control the 2nd RGB LED in Me Auriga .

Option [0] controls the brightness of red, green and blue in the range 0 to 255. "0" means no output and the LED is off. "255" is the maximum output and the indicator light is fully activated.

By setting values for these three colors you can create different light colors.

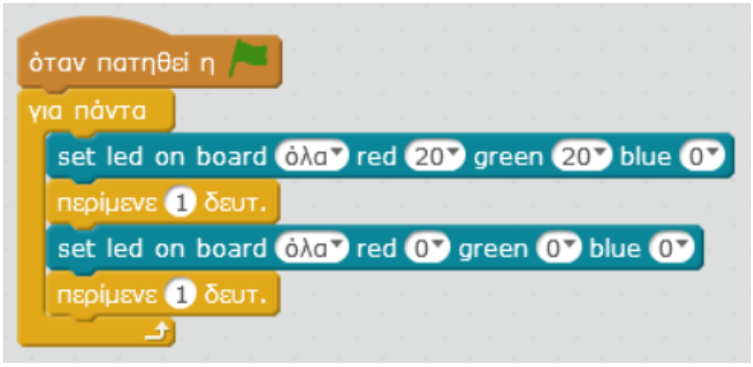
Try the command:

Task 1

If you want some commands to be executed continuously, then you place them in a "forever" command, which you find in the "Control" command group.

Because of the changes in the LEDs are done quickly, you can use the "wait" command, which you find in the "Control" command group.

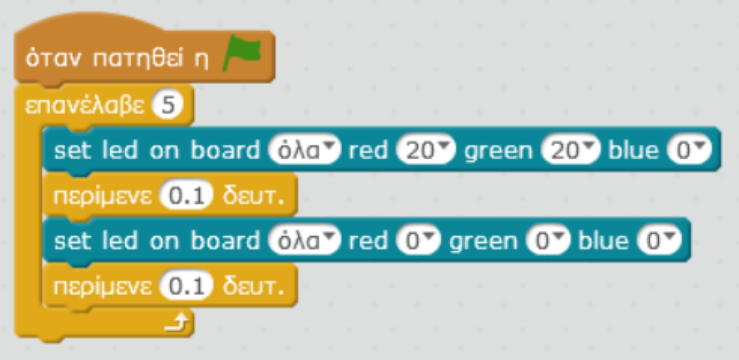
Try the following program. What do you notice?



Task 2

If you want some commands not to be executed forever but for a certain number of iterations, then use the "repeat" command

Try the following program. What do you notice?



Task 3

Change the previous program so that the red LEDs flash first 5 times, after the green LEDs 5 times and then the blue LEDs 5 times.

Task 4

Can you work with the lamps individually? Change the "all" option and create a program where the lights will light up in order, for example (first the 1st, then the 2nd, etc.). Make your own light show !

Lesson 2: Working with the Light Sensors of the robot

Description:

The students create code making the robots execute different commands depending on the value of the light sensor.

Learning Objectives:

to understand what a light sensor is

to understand what a variable is

to be more familiar with the hardware of mbot robotics

to use variables to store the data of a light sensor and interact with the robot

to build and execute selection structures using robotics

Expected results:

The students will be able to create programs using their computer, connect the robots and run the code. They will recognize the light sensors of the robot and create selection structures changing the brightness and the color of LED's.

Key issues:

programming, robotics, selection structure

Technologies:

mBot Ranger Robotics

Software:

mBlock

Age of students:

16-18

Number of students

70 (6 classes)

Didactic Hours:

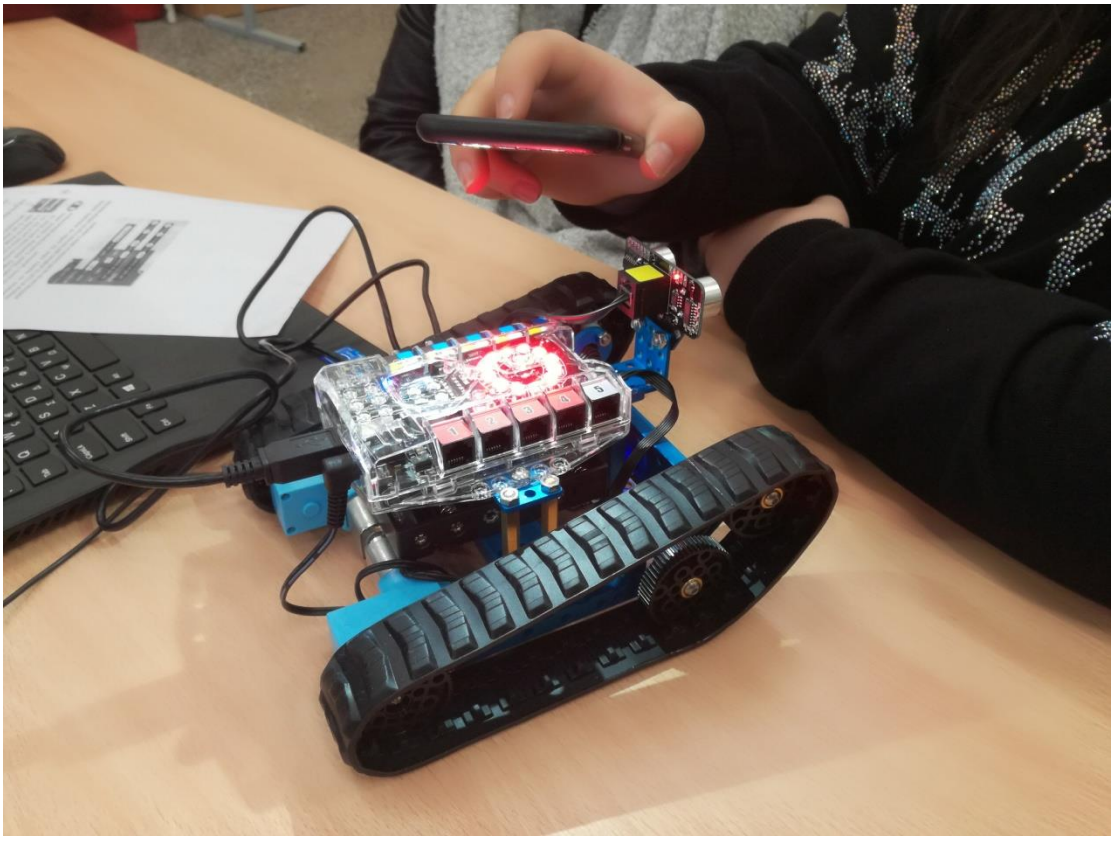
2 per class

Assessment:

The students in each class were divided in 4 teams and used laptops in order to create the code. The students acquired the necessary skills for their autonomous use of the software and the robots. They expressed their satisfaction for the educational material. No technical problems were observed.

YouTube Link:

https://www.youtube.com/watch?v=5QK23iGbUxU



Worksheet for the students

The Light Sensor of the mBot Ranger

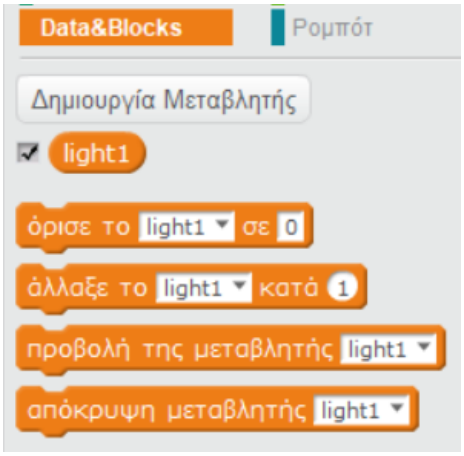
The Me Auriga of mBot Ranger has integrated two Light Sensors. To display the value of a Light Sensor we will use the corresponding tile from the "Robot" group in the mBlock program .

Sensor values range from 0 to 970. The "on board 1" option corresponds to light sensor 1 of Me Auriga while the "on board 2" option corresponds to light sensor 2.

Task 1

Create a variable for the sensor value

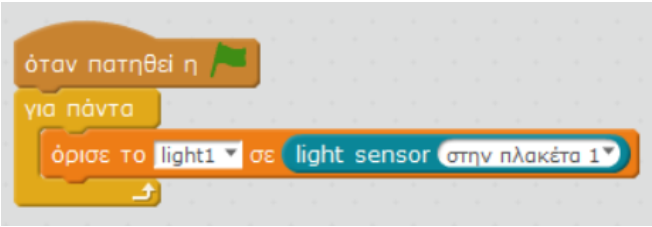
We will create a variable in which we will store the value of the sensor. Variables are used to store numbers or text in memory. To create a variable, go to the " Data & Blocks " group and click the "Create Variable" button. In the box that opens, enter the name of the variable. Name the variable light1 for this activity and press ok. In the next image we now see the available commands for this variable light1.



Task 2

Saving the sensor value variable to the variable

Then create the following code:



Connect the robot and press the green flag. You will notice that the light sensor values are displayed in the variable light1. If you cover the light sensor 1 with your hands, you will notice that the value of the light1 variable in the upper left corner of the scene is constantly changing. The closer your hand is to the light sensor, the less light the sensor detects, so the value of the variable will be lower.

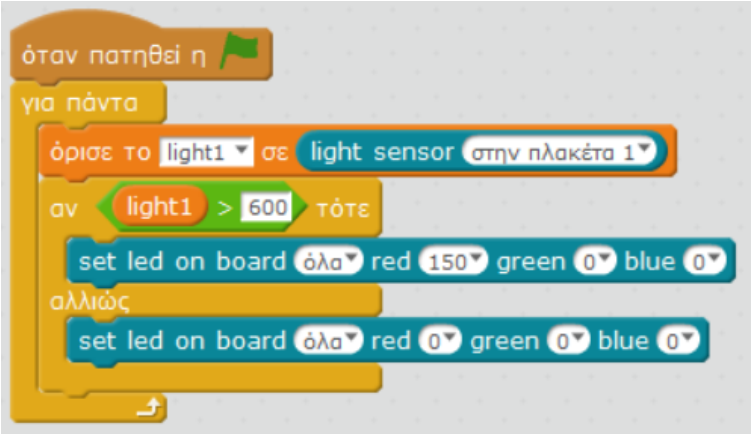
Task 3

The robot can execute different commands depending on the value of the light sensor. For example, we will create a program with which if the lighting is bright then the LEDs of the robot will turn red otherwise they will go out.

We decide that the lighting is considered bright when the value of the light sensor is greater than 600.

To check if the value of the light sensor is greater than 600, we use the command "if .. then .. else" from the command group "Check". Between "if" and "then" we put a condition. If the condition is true then the commands after "then" are executed. If the condition is false then the commands after "else" are executed. To create the condition we use the hexagonal green tiles from the group "Operators". In this exercise we use the tile with the operator > (larger).

Generate the following code. In the condition of this case we check if the value of the variable light1 (which is the value of the light sensor) is greater than the value of 600. Execute the code. What do you notice?



Lesson 3: Working with the Ultrasonic Sensor of the robot

Description:
The students create code making the robots move to different directions depending on the value of the ultrasonic sensor.

Learning Objectives:
to understand what a ultrasonic sensor is
to understand what a variable is
to be more familiar with the hardware of mbot robotics
to use variables to store the data of a ultrasonic sensor and interact with the robot
to build and execute selection structures using robotics

Expected results:
The students will be able to create code using their computer. The programs will be executed by the robot autonomously. They will recognize the ultrasonic sensor of the robot and create selection structures changing the movements of the robot.

Key issues:
programming, robotics, selection structure, sensors

Technologies:
mBot Ranger Robotics

Software:
mBlock

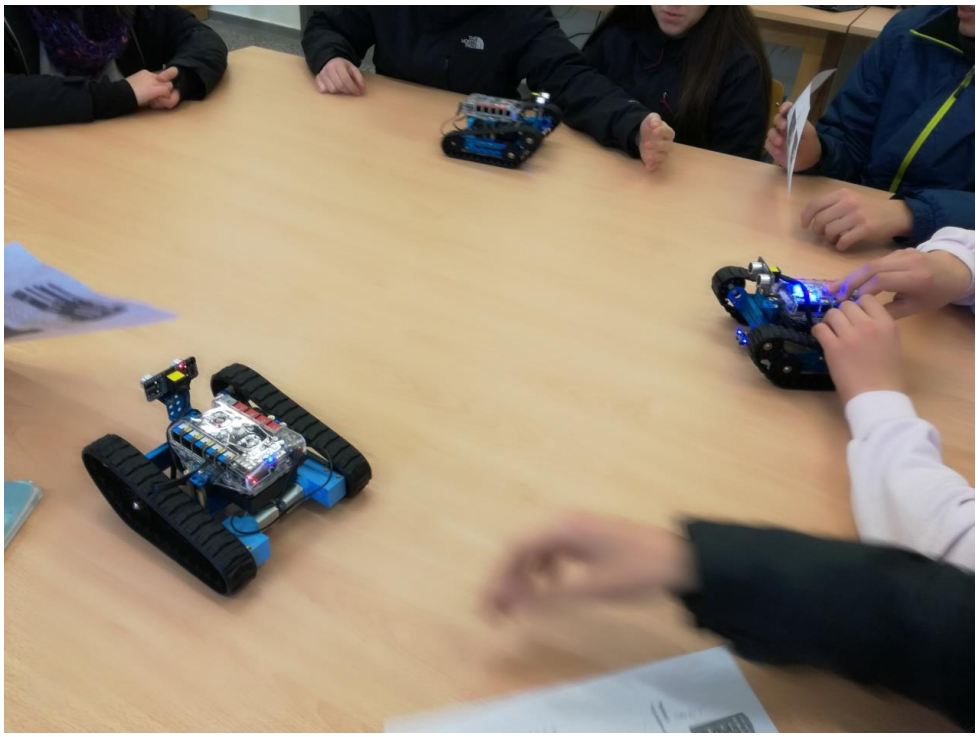
Age of students:
16-18

Number of students
70 (6 classes)

Didactic Hours:
2 per class

Assessment:
The students in each class were divided in 4 teams and used laptops in order to create the code. The students acquired the necessary skills for their autonomous use of the software and the robots. They expressed their satisfaction for the educational material and enjoyed the procedure of making the robot move. Some technical problems were reported about the connection between the laptop and the robot and the function of the motors.

YouTube Link:
https://www.youtube.com/watch?v=5QK23iGbUxU



Worksheet for the students
The Ultrasonic Sensor of the mBot Ranger

The ultrasound unit of the mBot Ranger consists of a transmitter, a receiver and a control circuit. When the ultrasonic transmitter receives a command, it emits high frequency sound waves. When the reflected sound waves are received from the receiver, Auriga calculates the elapsed time and converts the data into distance.

To display the value of Ultrasonic Sensor we will use the corresponding tile from the "Robot" group in the mBlock program . The default value "Port10" corresponds to the port to which the ultrasonic sensor is connected and of course can be changed.

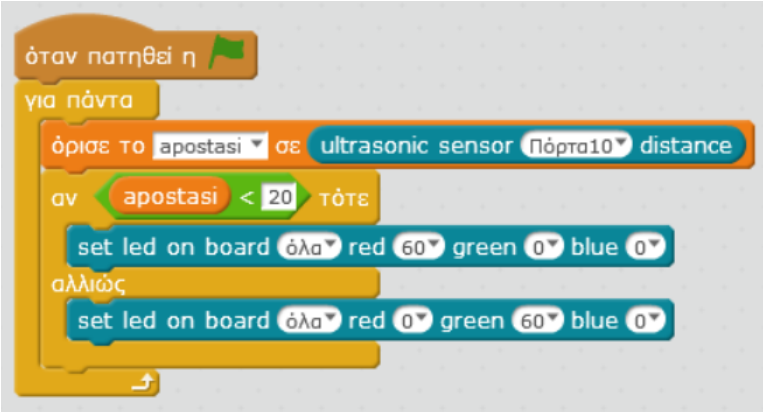
Task 1
Save the sensor value to a variable

In the "Data & Blocks" group, click the "Create Variable" button and create a variable named "apostasi". In this variable we will store the value of the sensor. Generate the following code:

Place your hand in front of the sensor and observe the change in the value as your hand approaches or moves away from the sensor. The value indicates the distance between your hand and the ultrasonic sensor. The price ranges from 3 to 400 cm.

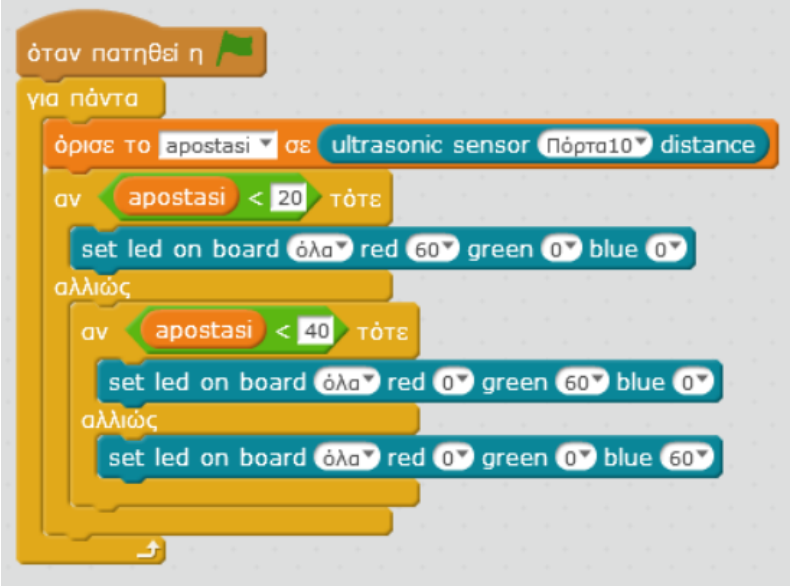
Task 2

The robot can execute different commands depending on the value of the ultrasonic sensor. For example, we will create a program with which if the distance between your hand and the ultrasonic sensor is less than 20 cm then the robot's LEDs will turn red otherwise they will turn green. Generate the following code.



Task 3

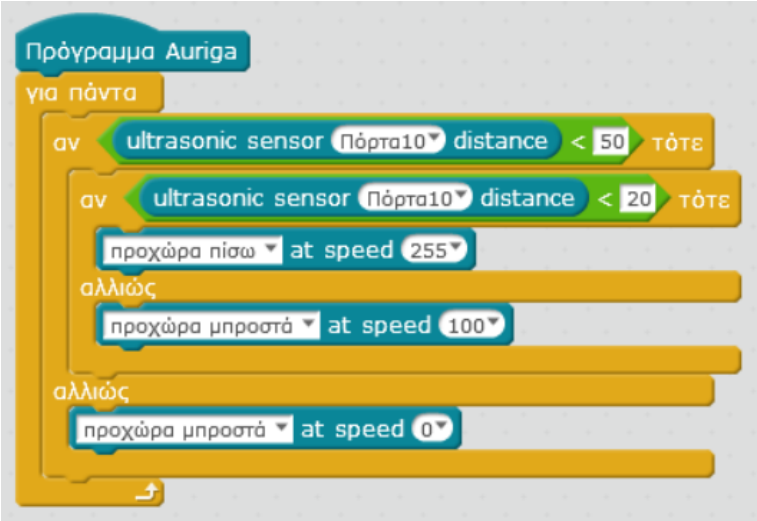
Generate the following code. What do you notice?



Task 4

When we want the program to be executed by the robot autonomously (without the robot being connected to the computer) then we use the "Auriga Program" as the first tile. After creating the code, right-click on "Auriga Program" and then select "upload to arduino". Then

press the "Upload to Arduino" button and the program is transferred and saved to the robot. Generate the following code. What do you notice?



Lesson 4: Working with the Ultrasonic Sensor of the robot

Description:

The students create code making the robots move on a black line depending on the value of the Line-Follower Sensor.

Learning Objectives:
to understand what a Line-Follower Sensor is and how it works
to understand what a variable is
to be more familiar with the hardware of mbot robotics
to use variables to store the data of a Line-Follower sensor and interact with the robot
to build and execute selection structures using robotics

Expected results:
The students will be able to create code using their computer. The programs will be executed by the robot autonomously. They will recognize the Line-Follower sensor of the robot and create selection structures making the robot move on a black line.

Key issues:
programming, robotics, selection structure, sensors

Technologies:
mBot Ranger Robotics

Software:
mBlock

Age of students:
16-18

Number of students
70 (6 classes)

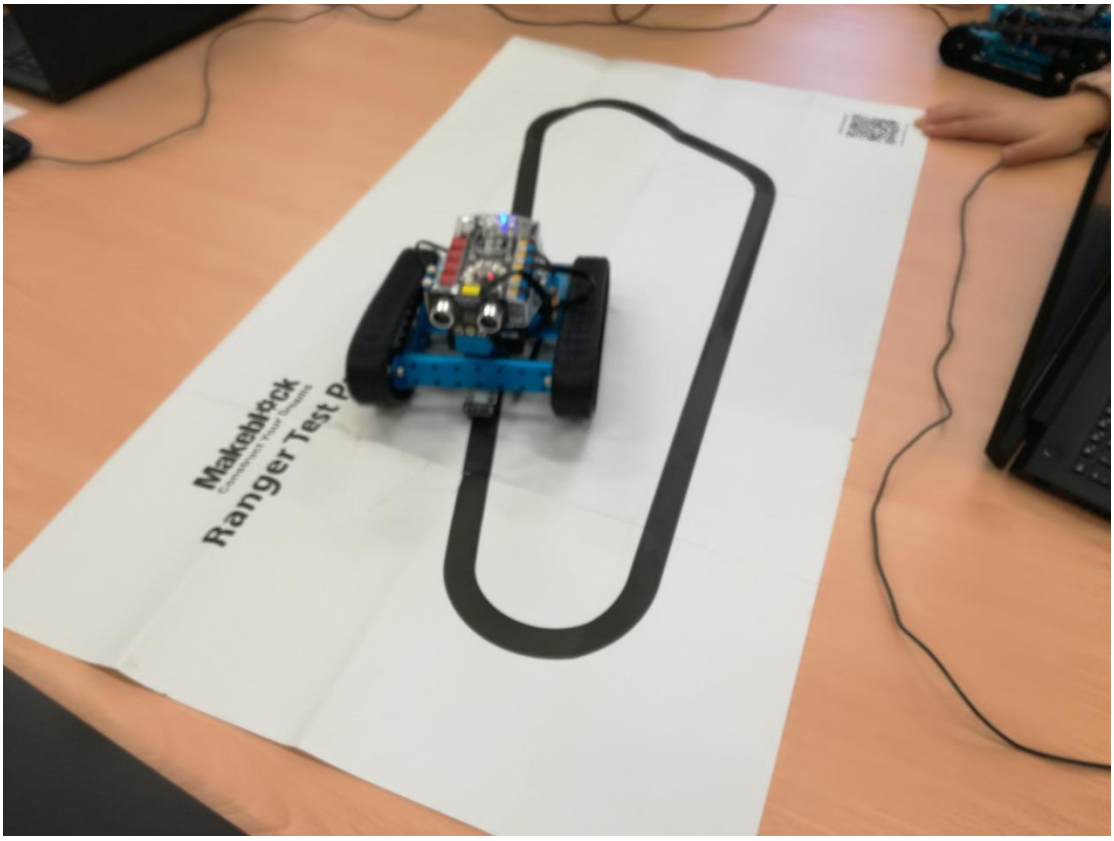
Didactic Hours:
1 per class

Assessment:
The students in each class were divided in 4 teams and used laptops in order to create the code. The students acquired the necessary skills for their autonomous use of the software and the robots. They expressed their satisfaction for the educational material and enjoyed the

procedure of the lesson. They experimented and tried to create the most effective code. No technical problems were reported.

YouTube Link:

https://www.youtube.com/watch?v=5QK23iGbUxU



Worksheet for the students

The Line-Follower Sensor of the mBot Ranger

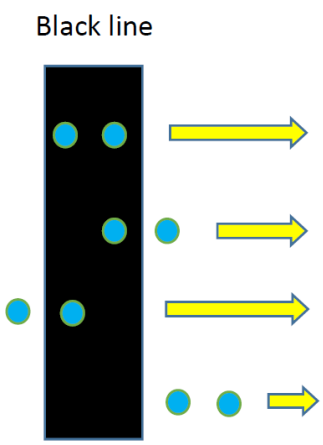
The Line-Follower Sensor will be used to move the mBot Ranger on a black orbit. To display the value of the Line-Follower Sensor we will use the corresponding tile from the "Robot" group in the mBlock program . The default value "Port9" corresponds to the port to which the sensor is connected .

Task 1

Save the sensor value to a variable

In the "Data & Blocks" group, click the "Create Variable" button and create a variable named "grammi". In this variable we will store the value of the sensor. Generate the following code:

Possible values are 0, 1, 2, 3. Put the robot so that the sensor is directly on the black line. The value should be 0. Move the robot left and right a little and see the changes in the value.



Left side sensor 1	Right side sensor 2	Line-follower sensor value
Black	Black	0
Black	White	1
White	Black	2
White	White	3

Task 2

Movement of the robot on the black orbit

Generate the following code. What do you notice?

LESSON PLANS – 3D Printing

Lesson 1: Using 3D printing technologies

Description:

The purpose of the lesson is to learn the basic concepts of designing and printing of 3D models. At the end of the course the students must be able to create a real object using the 3D printer. The modules of the course are:

- introduction to 3D printing technology by the teacher with the following topics: How 3D printers work, what can be made with a 3D printer, searching for 3d models in the world wide web (Thingiverse, MyMinifactory).
- design using TinkerCad Software. The teacher creates classes and nicknames for the students in the TinkerCad platform in order to organize the learning procedure. The link with the class code and the nicknames are shared to the students. The students visit the tinkercad website, watch tutorials and study in order to learn how to create a 3D model.
- slicing with Cura Software. The students print their own 3D model.

The shared presentations were produced during the implementation of the FabLab project.

Learning Objectives:

Students acquire knowledge including:

- the parts and the way that 3d printers function
- the materials used in 3d printing
- the areas of human activities in which 3d printing is used
- the available web free 3d design tools
- use of 3d applications and their tools, to design models for 3d printing including tinkercad

Students also acquire skills like

- operate a 3d printer
- set the proper properties to the printing software, in order to have a reliable print out
- prepare their 3d models for 3d printing
- recognize and to use productively the basic tools of a 3d design application.
- search the web to find proper 3d applications that cover their design needs.
- use the mouse and hot keys to operate and move in a 3d design space

Expected results:

At the end of the course students must be able to

- name and describe the basic parts of a 3d printer and the basic printing materials and 3d printing techniques
- describe the basic services of a 3d printing software

- describe the capabilities of a 3d modeling system
- name and describe the common functions of a 3d design software
- model and print their own creations
- Find designs online and create their own

Key issues:
3D design, 3D printer, creativity, 3D modelling

Technologies:
3D Technologies

Software:
TinkerCad, Cura

Age of students:
16

Number of students
70 (6 classes)

Didactic Hours:
6 per class

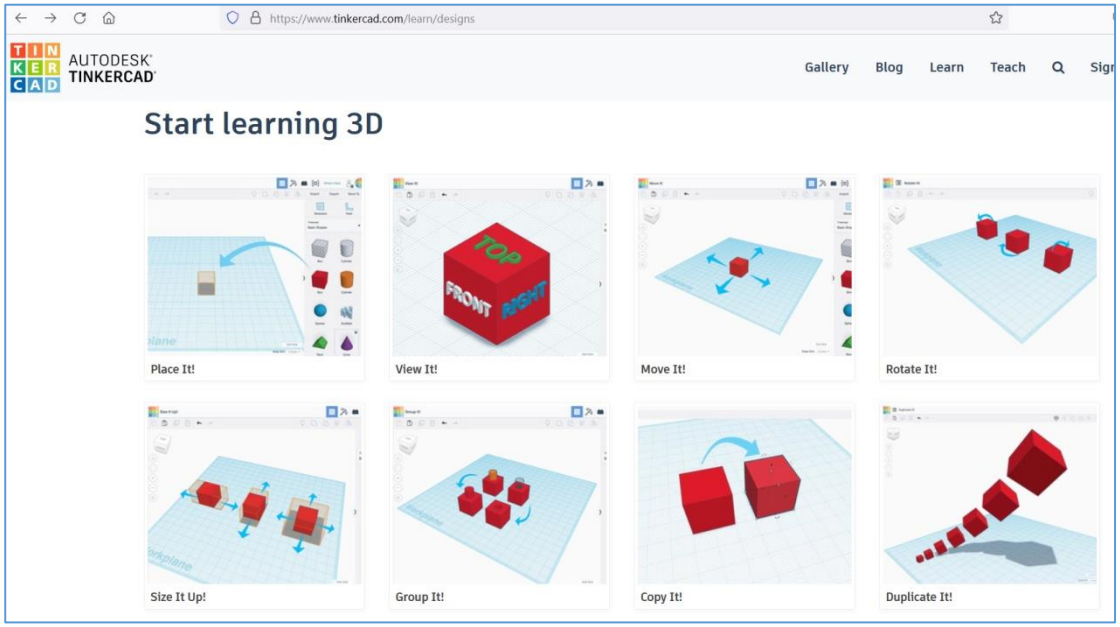
Assessment:
The training course aimed at 70 students (6 classes) from the 1st grade of the school. It was implemented in the School FabLab. The students used computers and laptops to have access to the presentations and design their 3D model with Tinkercad. They created the gcode by the "slicing" process with Cura Software installed at the lab server and printed with the Ultimaker 3D printer of the School FabLab. The students acquired the necessary skills for their autonomous use of 3D modeling software and created physical objects starting from original ideas. They used their imagination and creativity having positive feelings and enthusiasm during the lessons. The students expressed their satisfaction for the educational material and their joy that they were able to design and print their own object. No technical problems were observed.

Worksheet for the students

Task 1

Visit tinkercad.com website using the shared link with your class code. Type your nickname in order to have access to the platform. Click on Learn menu. You are going to learn how to create a 3D model. Place objects on the surface, create holes and learn how to move, rotate, resize and group them. You will also learn how to download your design and save it as a .stl file.

Link: https://www.tinkercad.com/learn/designs



Task 2

Design your 3D model using your imagination and creativity. The object can be a gadget like a keychain with your name. Download the .stl file.

Open it with Cura software and scale it 70%, see your printing options.

Save the file in .gcode extension and upload it.

LESSON PLANS – Augmented Reality

Lesson 1: Learning about Internet and World Wide Web with Augmented Reality

Description:

The object of the lesson is the process of teaching Informatics through the use of augmented reality. The chosen subject is titled "Internet and World Wide Web". The students learn about the history and the structure of the Internet and the World Wide Web and study about the most popular internet services. The teacher creates AR experiences enriching the content of the school book. The teacher designs markers like QR codes, text and images from the school book. The markers provide animations, images, 3D models, videos available on youtube channels and other repositories including the FabLab Learning Repository. The teacher adds the resources on the AR Lectio web platform and installs AR Lectio app in the school mobile devices (tablets). After the announcing of the theme of the lesson students are encouraged to watch videos, carry out experimental tasks with the help of devices and study discovering the AR content on the school book.

Learning Objectives:

to acquire knowledge about the history and the structure of the internet
to recognize the most popular internet services
to promote an active response with the content of the book
to motivate students to be engaged in the learning process

Expected results:

Using AR technology increases learning efficiency, facilitates students' training and cognitive activities, improves the quality of knowledge acquisition, provokes interest in a subject, promotes development of research skills. AR can add gamification to the learning process, grow student's motivation and positively influence their learning achievements.

Key issues:

Augmented Reality, Internet, World Wide Web

Technologies:

AR Technologies, Mobile Devices

Software:

AR Lectio

Age of students:

16

Number of students

70 (6 classes)

Didactic Hours:

1 per class

Assessment:

The training course aimed at 70 students (6 classes) from the 1st grade of the school. It was implemented in the School FabLab. The students used the school tablets to have access to the enriched content of the school book. At the end of the study, it is revealed that the students have a positive attitude towards AR applications. They want to use this kind of application in other courses as well. They indicate satisfaction with the application. No technical problems were observed.