Co-funded by the
Erasmus+ Programme
of the European Union

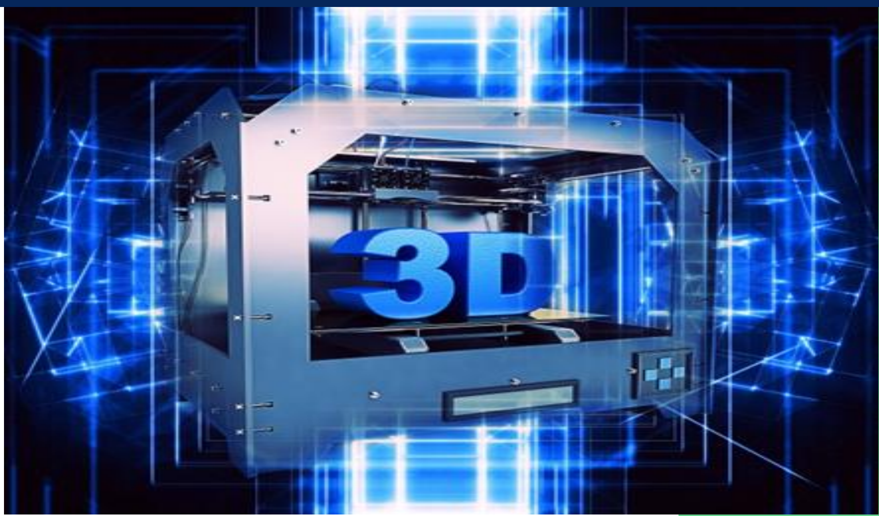
We're on the Web!

Visit us at:

https://makers-project.eu

## Classroom Guide to Teaching about and through 3D

# Teacher Training Program





Year of publication: **2023**

Editors: **C. Xanthaki, M. Kiagias, C. Koukouraki, P. Mantzarapi, N. Anastasakis, C. Koutsourelakis, and G. Cisarova-Dimitrova**

MAKER SCHOOLS
3D Design for Education

Project "MAKER SCHOOLS: Enhancing Student Creativity and STEM Engagement by Integrating 3D Design and Programming into Secondary School Learning"
(Agreement no. 2020-1-BG01-KA201-079274)

# Contents

**Description of the Educational Program ... 3**
Training content ... 3
Duration and workload ... 3
Software ... 3
Certificate of participation ... 3
**Part A, Module 1: Tinkercad basics ... 4**
Starting as students ... 4
Participation in training sessions and lab exercises ... 4
Activity 1.1: Introduction to Tinkercad ... 5
Activity 1.2: Starting with Tinkercad ... 7
Activity 1.3: Simple designs in Tinkercad ... 8
Class management in Tinkercad ... 10
Using Tinkercad as an educator ... 10
Graduation/transfer of student's work to another account ... 10
Evaluation of Module 1 – Tinkercad Basics ... 11
**Part A, Module 2: From basic shapes to objects ... 13**
Keyboard shortcuts ... 13
Activity 2.1: Car from three shapes ... 15
Activity 2.2: Watermill from basic shapes ... 15
Activity 2.3: Creative use of the Duplicate and Repeat commands ... 15
Activity 2.4: Simplified 3D model of a monument ... 17
Activity 2.5: Identifying and evaluating a video lesson for learning 3D design ... 17
Evaluation of Module 2 – From basic shapes to objects ... 19
**Part A, Module 3: Integration of 3D design into the educational process ... 20**
Activity 3.1 Design of an educational activity ... 20
Activity 3.2 Designing local monuments (school projects) ... 21
**Part A, Module 4: More complex 3D design and printing ... 24**
Activity 4.1: Constructing and printing a single object with hinges ... 24
**Part B, Module 5: Creative 3D design of organic shapes ... 25**
Activity 5.1 Detailed 3D model of an organic object composed of simple shapes ... 25
Activity 5.2 Organic shapes. Shape generators ... 26

Co-funded by the Erasmus+ Programme of the European Union

Activity 5.3 Create an original organic shape ........ 27

Activity 5.4 Exploring the relationship between modern and ancient art: The Ancient Picasso Project ........ 28

**Part B, Module 6: 3D design using programming techniques ........ 31**

The Codeblocks environment ........ 31

Activity 6.1 Create a simple design with Codeblocks ........ 32

Activity 6.2 Representation of mathematical relationships ........ 32

**Part C, Module 7: 3D printing in practice ........ 33**

The design ........ 33

Printing preparation ........ 34

The slicing process ........ 35

Print result ........ 41

**Internet Sources ........ 43**

Class management in Tinkercad and personal data ........ 43

Basic concepts of 3D design ........ 43

Keyboard shortcuts ........ 43

Co-funded by the Erasmus+ Programme of the European Union

# Description of the Educational Program

## Training content

The program consists of two parts. The first part aims at building basic knowledge and skills. This part is intended for all teachers taking the program. In the second part, teachers can choose additional subjects according to their interests.

**Part A:**

- Getting acquainted with the design environment
- Basic shapes
- Modifying objects
- Joining objects, removing material from objects
- Designing a 3D object from basic shapes
- Creating new shapes
- Using libraries
- Designing complex 3D objects and sets
- Integration of 3D design into educational practice.

**Part B:** Participants choose at least one of the following topics:

- Creative 3D design of organic shapes
- 3D design using programming.

**Part C:** 3D printing in practice

## Duration and workload

The program has a total duration of 6 weeks. Each week includes participation in a two-hour training sessions and self study/practice (2-3 hours).

## Software

The software to be used is Tinkercad. It is available for free (https://www.tinkercad.com) and enables:

a) creation of 3D models

b) 3D design by programming (Codeblocks)

c) circuit design.

In this training program we will focus on the creation of 3D designs and optionally, for those who choose it, on 3D design through programming (Codeblocks).

## Certificate of participation

Participants who complete the training program should be provided with a certificate describing the content and duration of the programme and the estimated workload.

Co-funded by the Erasmus+ Programme of the European Union

*The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

# Part A, Module 1: Tinkercad basics

## Starting as students

The purpose of this module is to introduce teachers to Tinkercad's core functions for 3D design and the teaching tools embedded in it. So even if the participating teachers have their own Tinkercad accounts, the training organizer should initially ask them to use Tinkercad as students. This means that participants will enter Tinkercad using the online link of the class and the unique Nickname the training organizer has created for them. As long as the participants use Tinkercad as students, all the designs they create will be visible to the training organizer and they will not have to submit assignments. In this way, teachers will get experience operating the classes in Tinkercad. Class management in Tinkercad is further discussed below.

Important note: *Participants have to Sing Up in the Tinkercad platform in order to see any links with materials inside this platform.*

## Participation in training sessions and lab exercises

For the successful completion of the program, the participants must complete the mandatory activities. The training sessions are intended for presenting the basic concepts and tools, providing examples and discussing the problems and questions that the participants have, while also giving time to discuss and perform short lab exercises. In addition, participants will evaluate the training material and the lab exercises.

Familiarity with 3D design requires time and personal effort. We have tried to select educational material that is suitable for personal autonomous study (e.g. video lessons). Most of the educational materials are in English. Familiarity with basic terminology in English offers both teachers and students the opportunity to use the very rich educational materials available in English. Participants will have these materials at their disposal before each training session so that they can study independently before or even after the training sessions. It is important that the participants do the exercises and to contribute to evaluation.

Module 1 includes three activities:

- **Activity 1.1**: Introduction to Tinkercad

  Introduction to Tinkercad through a series of video courses (we suggest alternative video courses available in English and Greek).

- **Activity 1.2**: Starting with Tinkercad

  Introductory exercises suggested by Tinkercad to overview the key functions for 3D design. It is available in English.

- **Activity 1.3:** Simple designs in Tinkercad

  Building on the gained knowledge, participants design relatively simple 3D models (we suggest alternative video courses available in English and Greek).

Co-funded by the Erasmus+ Programme of the European Union

## Activity 1.1: Introduction to Tinkercad

The participants watch the video lessons suggested below and replicate the displayed activities. The simplest approach is to stop watching the video from time to time and try the activities on Tinkercad. Participants can work with the pace and in the way that is most convenient for them.

***Video lessons in English***

| No | Description of lesson |
|---|---|
| **1** | **Content**: user interface, navigation views, preferences<br>**Duration**: 23 min<br>PromoAmbitions (2018). Tinkercad Tutorial Part 1 - (Interface and Movement) https://www.youtube.com/watch?v=2JFxtUIOnEI |
| **2** | **Content**: shape manipulation, scaling of shapes<br>**Duration**: 20 min<br>PromoAmbitions (2018). Tinkercad Tutorial Part 2 - (Shape Manipulation and Scaling) https://www.youtube.com/watch?v=Xy6EuqocJKI |
| **3** | **Content**: group and ungroup tool, hole tool, align tool, flip tool<br>**Duration**: 17 min<br>PromoAmbitions (2018). Tinkercad Tutorial Part 3 - (Group, Hole, Align, and Flip Tool) https://www.youtube.com/watch?v=hbQww7pWGt4 |
| **4** | **Content**: workplane, ruler, blocks and bricks environment<br>**Duration**: 21 min<br>PromoAmbitions (2018). Tinkercad Tutorial Part 4 – (Workplane, Ruler, Blocks and Bricks) https://www.youtube.com/watch?v=aa2uboMStVQ |
| **5** | **Content**: creating circular and linear patterns, slicing objects, positioning objects for 3D printing purposes<br>**Duration**: 19 min<br>PromoAmbitions (2018). Tinkercad Tutorial Part 5 - (Circular Patterns and Slicing) https://www.youtube.com/watch?v=J_M8LGsElJs |
| **6** | **Content**: importing SVG, OBJ, and STL files, exporting designs, downloading designs, collaborating with others on a design<br>**Duration**: 13 min<br>PromoAmbitions (2018). Tinkercad Tutorial Part 6 - (Import Export and Collaborating) https://www.youtube.com/watch?v=1sVJZE2oVHs |

Co-funded by the Erasmus+ Programme of the European Union

*The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

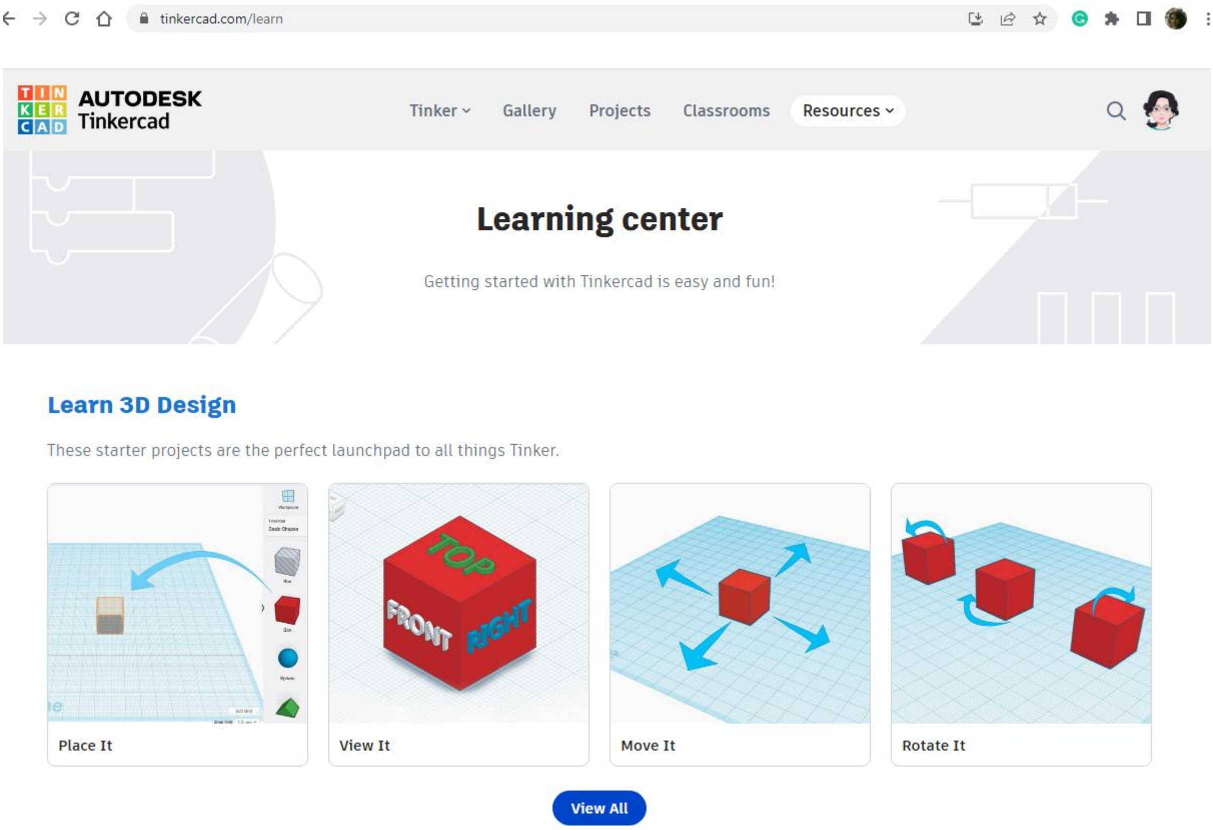
*Video Lessons in the Greek language*

| No | Description of lesson |
|---|---|
| 1 | **Contents:** brief description of the interface and workspace, creating an object, properties (radius, steps, length, width, height), zoom, view modes<br>**Duration:** 8 min<br>Kostas Nikolopoulos. (2018). Tinkercad for beginners 02 Greek. https://www.youtube.com/watch?v=odV7Lqfa_j4 |
| 2 | **Contents**: move, rotate, resize objects<br>**Duration**: 5 min<br>Kostas Nikolopoulos. (2018). Tinkercad for beginners 03 Greek. https://www.youtube.com/watch?v=vvgYSnMNAb0 |
| 3 | **Contents**: simultaneous selection of two objects, grouping and ungrouping, union and volume removal, object color, object transparency, hiding and showing objects, lock editing, mirror, align<br>**Duration**: 7 min<br>Kostas Nikolopoulos. (2018). Tinkercad for beginners 04 Greek. https://www.youtube.com/watch?v=nTgPSzJyjYs |
| 4 | **Contents**: copy, paste, duplicate, delete, undo, redo<br>**Duration**: 6 min<br>Kostas Nikolopoulos. (2018). Tinkercad for beginners 05 Greek. https://www.youtube.com/watch?v=XAqzIVP--gk |
| 5 | **Contents**: import, export<br>**Duration**: 4 min<br>Kostas Nikolopoulos. (2018). Tinkercad for beginners 06 Greek. https://www.youtube.com/watch?v=3nB_bsvEnFI |

| **Evaluation and feedback:** The participants rate this activity by answering the following questions | |
|---|---|
| How much time did you spend on the activity? | |
| Was this your first contact with similar software? What did you learn? | |
| Where did you experience difficulties? | |
| Would you recommend Tinkercad to students? | |

Co-funded by the Erasmus+ Programme of the European Union

## Activity 1.2: Starting with Tinkercad




The participants familiarize themselves with the basic functions of Tinkercad, performing 12 short introductory exercises (starters), one for each function. They can repeat the exercises as many times as necessary or refer to them when they need to remember exactly how the corresponding function is performed. The exercises are available at the following address:

https://www.tinkercad.com/learn

| **Evaluation and feedback:** The participants rate this activity by answering the questions below | |
|---|---|
| How much time did you spend on the activity? | |
| What did you learn? | |
| Where did you experience difficulties? | |
| Would you recommend the exercise to your students? | |

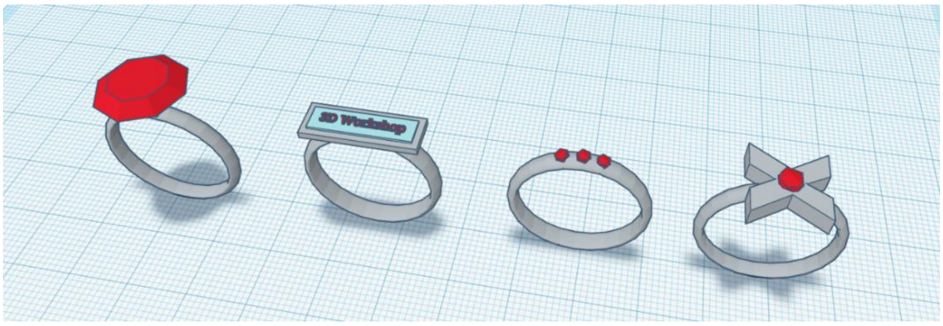
Co-funded by the Erasmus+ Programme of the European Union

*The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

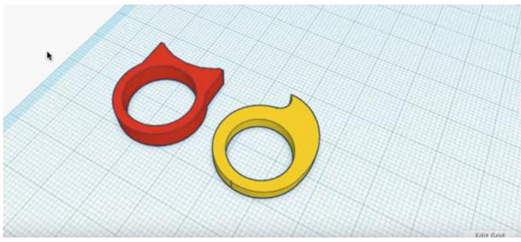
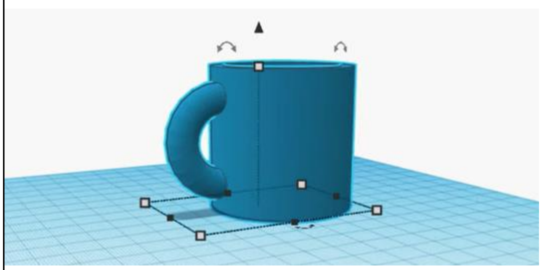
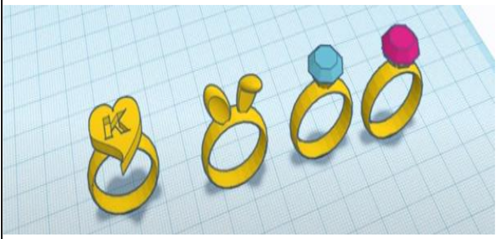
## Activity 1.3: Simple designs in Tinkercad

In this activity is the participants have to combine several basic functions of Tinkercad to design simple 3d objects.

- First the participants have to watch at least one of the video lessons suggested below and follow the steps in order to design a 3D object shown in the video lesson (a ring or a mug).
- After reproducing successfully at least one 3D design the participants can be creative: they design their own 3D objects
- Then the participants can share their designs with others and create a unique collection of 3D objects.



**Video lessons for simple designs**

| | |
|---|---|
|  | Video lesson in English: Jarrod Carter (2018). Tinkercad - 3D Printed Rings.<br>https://www.youtube.com/watch?v=JFB-UelHecc (from 1.40' onwards)<br>**Duration**: 13 min |
|  | Alternative video lesson in English: Kevin Welch (2020). Making a Mug in Tinkercad. https://www.youtube.com/watch?v=cXlvd-1VDX8<br>**Duration**: 13 min |
|  | Alternative video lesson in Greek: Yiannis Arvanitakis. (2020). We design jewellery in Tinkercad. https://www.youtube.com/watch?v=rF5HBdK0a8M<br>(from 1.20' onwards)<br>**Duration**: 9 min |

Co-funded by the Erasmus+ Programme of the European Union

*The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

| **Evaluation and feedback:** The participants rate the activity 1.3 "Simple designs in Tinkercad" by answering the questions below | |
|---|---|
| How much time did you spend on the activity? | |
| What did you learn? | |
| Did you experience difficulties?<br>Describe any what kind of problems you had.<br>What do think needs to be done to overcome these problems? | |
| Would you recommend the exercises to your students? | |

## Class management in Tinkercad

Tinkercad allows for the creation of different categories of users: teachers, parents and students. Teachers can create classes and register their students. Each class has its own hyperlink and each student in the class is nicknamed. The use of classes in Tinkercad brings two important advantages:

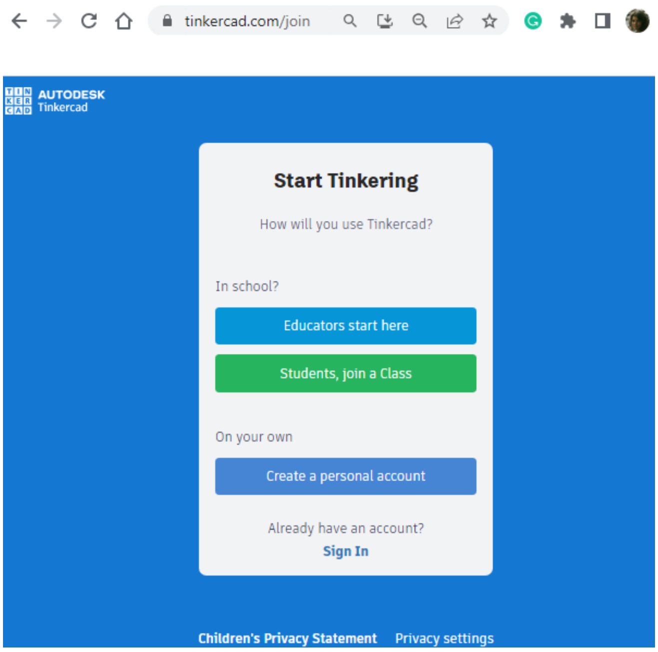
- Simplification of communication between students and teachers. Teachers can see and modify all their class plans, and students do not have to "submit" their assignments. The Classroom function simulates that of the school lab: for each class the teacher can continuously monitor the progress of the students by seeing the designs they create and the tasks they have completed. The teacher can send a message to the student with comments/corrections. The student can see the teacher's comments for each project separately.
- Protection of students' personal data. Tinkercad is GDPR compliant. Students do not need to have a Tinkercad account or provide their name or email. They can participate in classes using only a) the class link and b) the unique nickname created for them by the teacher. For greater protection, the teacher can activate the Safe Mode option by limiting students' access to the community and the ability to communicate with other users (more information about safe mode is available at:

  https://www.tinkercad.com/blog/tinkertips-safe-mode).

## Using Tinkercad as an educator

To create their own classes in Tinkercad the participants will need to register at Tinkercad. They should follow the procedure provided for teachers (Educators Start Here). If they are already registered with Tinkercad, they will choose 'Sign In' to sign in to the program. The ability to create classes is available at: https://www.tinkercad.com/classrooms.

If participants need help with Tinkercad Classrooms, they should consult the tutorials at https://www.tinkercad.com/classrooms-resources.




## Graduation/transfer of student's work to another account

At the end of the course, students have the option transfer their designs to personal accounts (either their own or their parents'). During the transfer all the tasks the student has worked on are entered into the selected account, organised in a folder that automatically takes the name of the class the student was studying.

Co-funded by the Erasmus+ Programme of the European Union

*The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

## Evaluation of Module 1 – Tinkercad Basics

After completing the activities in Module 1, the participants should fill in the following feedback form (could be designed as a Google form):

| Question | Rating |
| --- | --- |
| The suggested study time for this module was 5 hours. Was this time about right? | Rate from 1 (insufficient) to 5 (unnecessarily long) |
| The purpose of the module was to get familiar with the basic functions of Tinkercad such as: creating, moving, modifying, multiplying, viewing & composing shapes and objects. To what extent was this purpose achieved? | Rate from 1 (Not at all) to 5 (Fully achieved) |
| After completing the module, which functions do you feel you know well? | Choose all applicable options:<br>☐ Precise movement<br>☐ Precise definition of dimensions<br>☐ Object view on the drawing surface<br>☐ Create a simple copy<br>☐ Create multiple copies (duplicate)<br>☐ Relative placement of objects (align)<br>☐ Composition of solid objects<br>☐ Create holes<br>☐ Other: …………………………….. |
| Which of the following did you struggle with or continue to struggle with? | Choose all applicable options:<br>☐ Precise movement<br>☐ Precise definition of dimensions<br>☐ Object view on the drawing surface<br>☐ Create a simple copy<br>☐ Create multiple copies (duplicate)<br>☐ Relative placement of objects (align)<br>☐ Composition of solid objects<br>☐ Create holes<br>☐ Other: …………………………….. |
| Which activities would you recommend to your students in order to learn the basic design principles of Tinkecad and use them in your course work? | Choose all applicable options:<br>☐ Activity 1.1: Introduction to Tinkercad<br>☐ Activity 1.2: Starting with Tinkercad |

Co-funded by the Erasmus+ Programme of the European Union

| | |
|---|---|
| | ☐ Activity 1.3: Simple designs in Tinkercad<br>☐ Other: ……………………………. |

## Part A, Module 2: From basic shapes to objects

In this module the participants will practice designing more complex objects from the basic shapes. Module 2 includes the following activities:

- **Activity 2.1**: Car from three shapes

  Creation of more complex shapes from basic ones
- **Activity 2.2**: Watermill from basic shapes

  Creation of more complex shapes from basic ones
- **Activity 2.3:** Creative use of the Duplicate and Repeat commands

  Creation of complex shapes with repeating patterns
- **Activity 2.4:** Simplified 3D model of a monument

  Creation of complex models by taking into account precise dimensions and ratios
- **Activity 2.5:** Identifying and evaluating a video lesson for learning 3D design

### Keyboard shortcuts

As they move on to create more complex shapes, the participants should be encouraged to use additional features provided by keyboard shortcuts, e.g.:

- Change the size of an object by keeping its center stable (resizing with the **Alt key)**
- Change the size of an object by keeping the proportions constant (resizing with the **Shift key).**
- More shortcuts are show in the figure below:

Co-funded by the Erasmus+ Programme of the European Union

AUTODESK® TINKERCAD®

# KEYBOARD SHORTCUTS

Legend: Ctrl = Cmd / Alt = Option

## MOVING OBJECT(S)
(Using keyboard)

| | |
|---|---|
| Move along X/Y axis | ← / ↑ / ↓ / → |
| Move along Z axis | Ctrl + ↓ / ↑ |
| ×10 Nudge along X/Y axis | Shift + ← / ↑ / ↓ / → |
| ×10 Nudge along Z axis | Ctrl + Shift + ↓ / ↑ |

## KEYBOARD + MOUSE SHORTCUTS
(Press and hold the keys, then click and drag the mouse)

| | |
|---|---|
| **Duplicate** dragged object(s) | Alt + Drag left mouse button |
| **Select** multiple object(s) | Shift + Left mouse button |
| 45° rotation | Shift (Hold while rotating) |
| Scale in one direction | Alt + Hold side handle |
| Scale in two directions | Alt + Hold corner handle |
| Uniform scale | Shift + Hold corner handle |
| Uniform scale in all directions | Alt + Shift + Corner handle |
| Uniform scale in all directions | Alt + Shift + Top handle |

## VIEWING DESIGNS
(With the help of a mouse or a mouse pad)

| | |
|---|---|
| Orbit the view | Right mouse button |
| Orbit the view | Ctrl + Left mouse button |
| Pan the view | Shift + Right mouse button |
| Pan the view | Ctrl + Shift + left button |
| Zoom the view in or out | Mouse scroll wheel |
| Zoom-in | + |
| Zoom-out | - |
| Fit selected object(s) into view | F |

## OBJECT SETTINGS

| | |
|---|---|
| **Transparency** toggle | T |
| Turn object(s) into **Holes** | H |
| Turn object(s) into **Solids** | S |
| **Lock** or **Unlock** object(s) | Ctrl + L |
| **Hide** object(s) | Ctrl + H |
| **Show all** hidden object(s) | Ctrl + Shift + H |

## TOOLS AND COMMANDS

| | |
|---|---|
| **Copy** object(s) | Ctrl + C |
| **Paste** object(s) | Ctrl + V |
| **Duplicate** object(s) in place. | Ctrl + D |
| **Delete** object(s) | Del |
| **Undo** action(s) | Ctrl + Z |
| **Redo** action(s) | Ctrl + Y |
| **Redo** action(s) | Ctrl + Shift + Z |
| **Group** object(s) | Ctrl + G |
| **Un-group** object(s) | Ctrl + Shift + G |
| **Align** object(s) | L |
| **Flip/Mirror** objects(s) | M |
| **Select** all object(s) | Ctrl + A |
| Place a **Ruler** | R ( Shift toggle midpoint/center ) |
| Place a **Workplane** | W ( press Shift to flip direction ) |
| **Drop** object(s) to workplane | D |

Visit www.tinkercad.com/learn for more tips, step-by-step tutorials, and easy projects. Happy Tinkering!

Source:*https://blogdottinkercaddotcom.files.wordpress.com/2018/08/tinkercad-keyboard-shortcuts_revised-8-31-182.pdf*

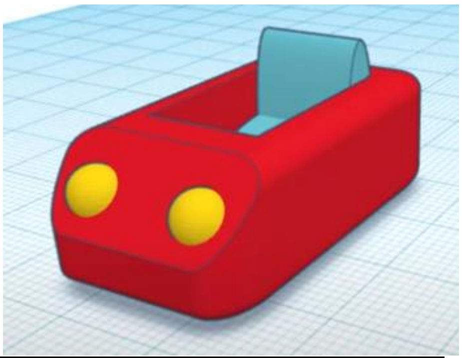
Co-funded by the
Erasmus+ Programme
of the European Union

*The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

### Activity 2.1: Car from three shapes

Duration: 30 minutes

The participants watch the video lesson suggested below. They follow the steps to create their own version of the car and save the model in a file.

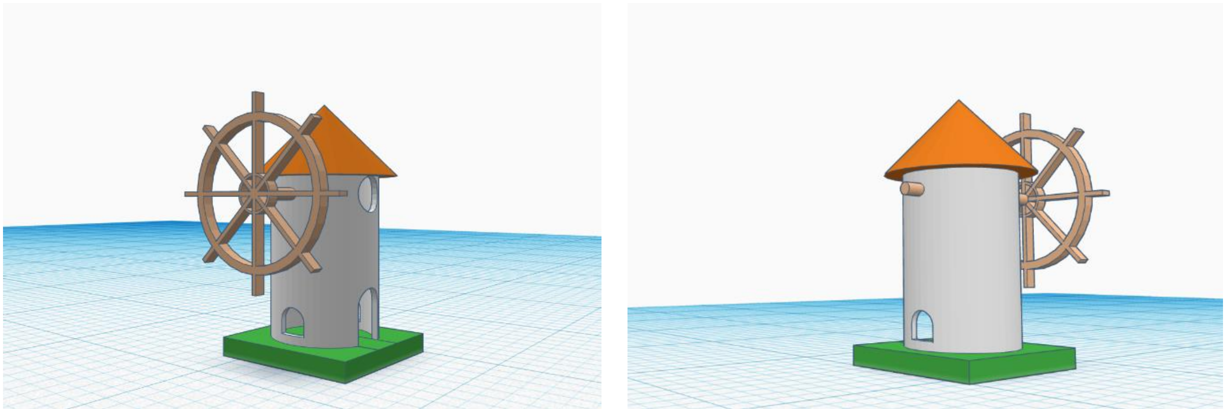


Video lesson in English: Jumekubo4edu (2020). 21. Tinkercad - From Basic Shapes to Complex Object. https://www.youtube.com/watch?v=77O3eY2Oq0s

Duration: 9 minutes

### Activity 2.2: Watermill from basic shapes

The participants watch the video lesson created in the frame of the MAKERS project and referenced below. They follow the steps to create their own version of a watermill and save the model in a file.



*The watermill shown from two different points of view*

A 3D model of the watermill is available in Tinkercad and it is open to all Tinkercad users to view and remix: https://www.tinkercad.com/things/gPj22lRkokh

Video lesson created in the frame of the MAKER SCHOOLS project (image and sound only, no language requirements). Panagiota Mantzarapi (2023). Watermill (3D design with Tinkercad). https://youtu.be/WKUFWiMt7Jk

Duration: 14 minutes

### Activity 2.3: Creative use of the Duplicate and Repeat commands

Duration: 30 minutes

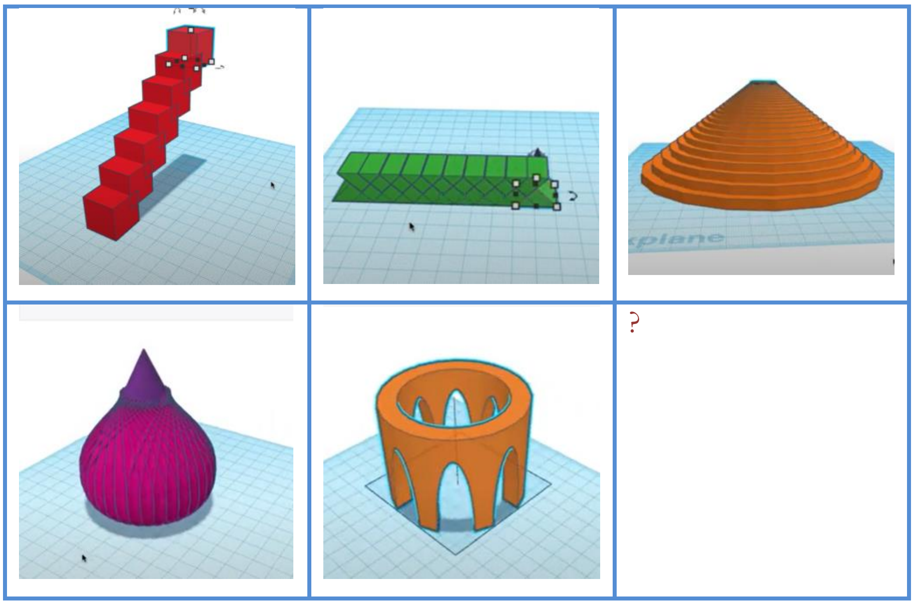
A) The participants watch the video lesson suggested below. They use the Duplicate and Repeat commands to produce shapes similar to those in the video.

Co-funded by the Erasmus+ Programme of the European Union

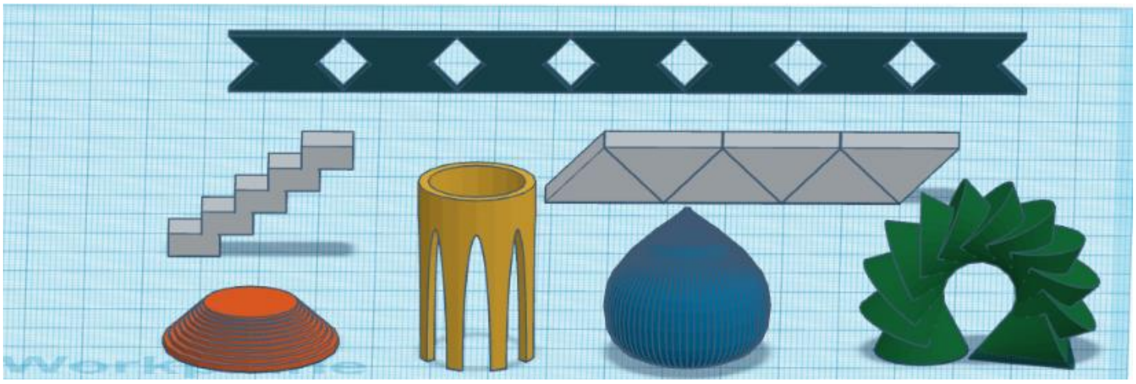
*The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

| |
|---|
| Video lesson in English: Jumekubo4edu (2020). 22. Tinkercad Duplicate and Repeat" https://youtu.be/ajTHzA5Sj54<br><br>Duration: 7.5 minutes |

B) The participants create at least one shape on their own, using the Duplicate & Repeat commands and save their designs in a file.




C) The participants try to be creative and imaginative and produce more shapes using the Duplicate and Repeat command:

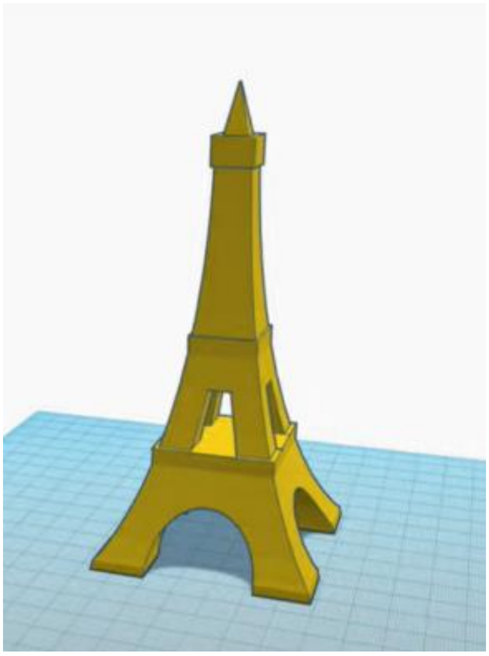


D) The participants identify natural phenomena and mathematical relationships that can be illustrated using the Duplicate and Repeat command.

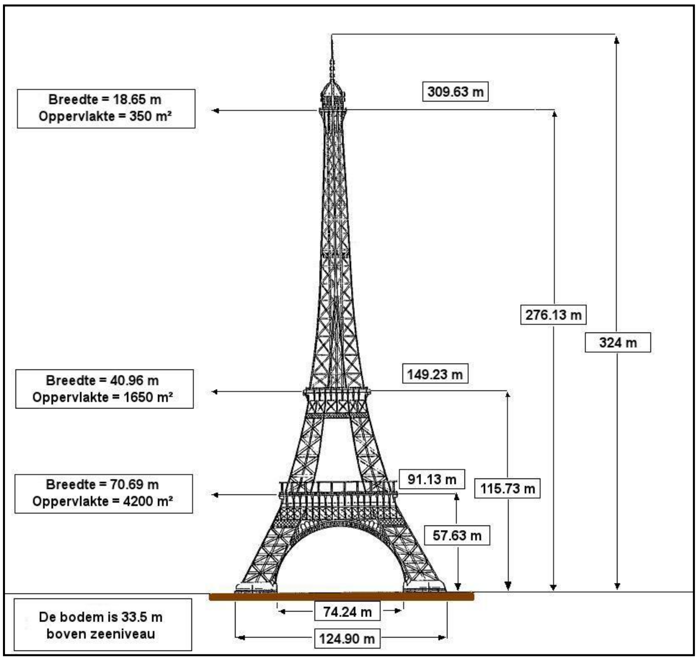
## Activity 2.4: Simplified 3D model of a monument

(Local monuments can be designed, e.g. Chania lighthouse)

Duration: 60 minutes



*Simplified three-dimensional model*




*Real Dimensions (*)*

*Source: [https://commons.wikimedia.org/wiki/File:Dimensions_tour_Eiffel-NL.JPG](https://commons.wikimedia.org/wiki/File:Dimensions_tour_Eiffel-NL.JPG)*

A) The participants watch the video lesson suggested below, and follow the proposed process of building a simplified model of the Eiffel Tower.

> Video lesson in English: Eunny (1998). "16) Make Simple Eiffel Tower with Tinkercad + 3D Printing | 3D modeling How to make and design", https://youtu.be/LOKpUSnjHao
>
> Duration: 9 minutes

B) After studying the figure with the actual dimensions of the tower, the participants calculate the dimensions of the 3D model so that its proportions correspond to the actual ones.

C) The participants design the 3D model in Tinkercad.

D) The participants think about 3D models of monuments that could be of interest to them and their students.

## Activity 2.5: Identifying and evaluating a video lesson for learning 3D design

The participants find a video lesson that they would like to work with their students. They try to replicate the design process that is suggested in the video. On that basis they evaluate the video lesson. Then they describe their proposal in the document suggested below.

Co-funded by the Erasmus+ Programme of the European Union

*The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

| | To be completed by the teacher |
|---|---|
| Teacher's name | |
| Description of the exercise | |
| Title | |
| Link to the video lesson | |
| Are the instructions accurate enough for someone to replicate the design? Give a printscreen of the final design | |
| Time needed to reproduce the design | |
| What will students learn by completing the lesson | |
| Other activities that could be included | |

Co-funded by the Erasmus+ Programme of the European Union

## Evaluation of Module 2 – From basic shapes to objects

After completing the activities in Module 2, the participants should fill in the following feedback form (could be designed as a Google form):

| Question | Rating |
|---|---|
| How accurate were the instructions for the designs? | Rate from 1 (incomplete) to 5 (absolutely clear and sufficient) |
| How long did it take you to implement the activities? | Choose one option:<br>☐ About 2 hours<br>☐ About 2.5 hours<br>☐ About 3 hours<br>☐ About 3.5 hours<br>☐ More than 4 hours |
| Which of the following do you think your students will have learned by completing the module? | Choose all applicable options:<br>☐ Using and customizing basic shapes<br>☐ Union of different objects<br>☐ Subtracting material from the object<br>☐ Creating complex shapes from simpler shapes<br>☐ Creating simplified 3D models of various objects<br>☐ Combinations of composite and basic shapes<br>☐ Understanding how to create a 3D model of an object<br>☐ Other: ………………………………………… |
| What activities would you recommend to your students in order to learn to design simple objects using Tinkercad? | Choose all applicable options:<br>☐ **Activity 2.1**: Car from three shapes<br>☐ **Activity 2.2**: Watermill from basic shapes<br>☐ **Activity 2.3:** Creative use of the Duplicate and Repeat commands<br>☐ **Activity 2.4:** Simplified 3D model of a monument<br>☐ **Activity 2.5:** Identifying and evaluating a video lesson for learning 3D design<br>☐ Other: ………………………………………… |

Co-funded by the Erasmus+ Programme of the European Union

# Part A, Module 3: Integration of 3D design into the educational process

## Activity 3.1 Design of an educational activity

The participants suggest an activity (it may last one or more sessions) that they would be interested in implementing with their students. The activity should involve 3D design and possibly 3D printing. They describe their suggestions in the form suggested below.

| | To be completed by the teacher / teacher team |
|---|---|
| Teacher's name or name of the teacher team | |
| Description of the educational activity | |
| Title | |
| Recommended age of students (range) | |
| Recommended number of students | |
| Related activities, courses or objects | |
| Time needed to design (and possibly print) the 3D model | |
| Objectives<br>*Describe the knowledge, skills and competences that will be acquired by students participating in the activity. You can mention knowledge, as well as both technical and transversal skills (collaboration, problem-solving, etc.)* | |
| Mode of work<br>▪ Steps/individual tasks that will be implemented<br>▪ Cooperation with other schools<br>▪ Will there be a difference in the planned contribution/tasks and the roles of different schools in the activity<br>▪ How often will you communicate with the teachers from other schools<br>▪ Will you set up working groups with students from | |

Co-funded by the Erasmus+ Programme of the European Union

| | |
|---|---|
| different schools? | |
| Results of the project<br>*What will be created in the course of the activity, e.g. 3D designs, 3D objects, physical computing constructions, python programs, presentations, videos, websites, materials.* | |

## Activity 3.2 Designing local monuments (school projects)

Duration: 4 hours

### Introduction

Creating a 3D model of a local monument or a historical building can be a part of bigger project and can be integrated into the school curriculum in various subjects such as History, Art, Technology, Engineering. The students can learn more, not only about the construction, the shape and the dimensions of the monument but also about when it was created, what it represents, and why it is important. In this activity we shall show, as an example, how to create 3D models of monuments located in Chania, Greece.

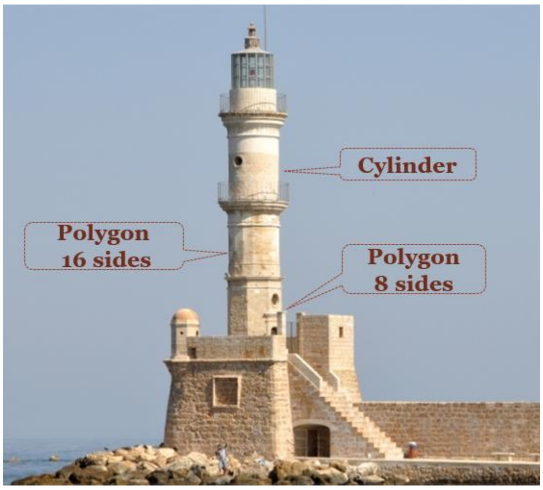
### Step 1. Gather information

The students can do online research, or where appropriate, search in local archives in libraries, museums, newspapers, universities, or in the city or state archives.

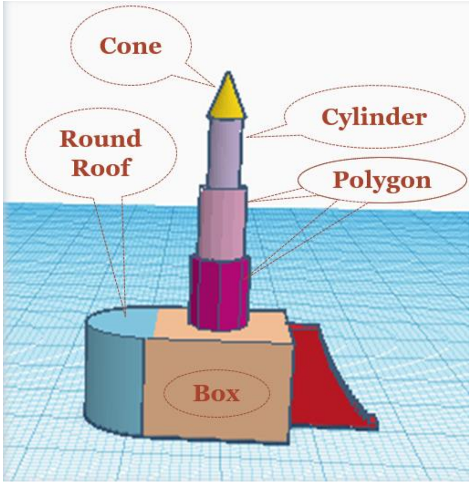
A field trip to the local monument will allow the students to observe the monument closely, and gather the information needed for creating the 3D model, by taking photos from different points of view, drawing sketches and taking measurements.

### Step 2. Create a simplified 3D model using basic shapes

Creating a 3D model for a complex object, such as a monument, seems like an overwhelming task. The method we suggest is to create at first a simplified 3D model of the object using basic shapes. Then we use the tools available in Tinkercad to create a more detailed 3D model of the monument.



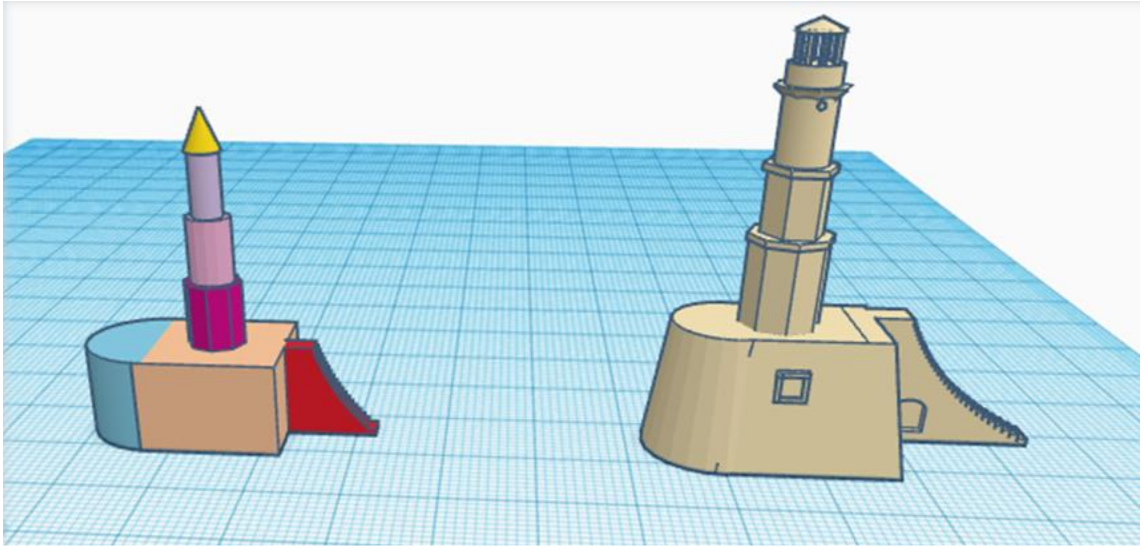

Breaking the object into basic shapes




Using basic shapes to create a simplified 3D model

### Step 3. Create a detailed model

After creating a simple 3D model we can add as much detail as we need by adding parts to our basic model or replacing some parts with more detailed ones. When developing the parts of a detailed model we use the same strategy: we break the part we want to model into basic shapes. For example, if we want to add a staircase, we can design it step by step!



*Adding or replacing parts to the initial 3D model (on the left) to create a detailed 3D model (on the right)*

### Step 4. 3D Print

After completing the 3D model we can export and print the design using a 3D printer. At first we can print a smaller version of the object, to see if any adjustments or corrections have to be done to the model. After finalizing the 3D model we can print a larger and version in finer quality. Electronic components, such as LEDs, can then be embedded into the 3D printed monuments to make them even more interesting!

Co-funded by the
Erasmus+ Programme
of the European Union

### Step 5. Share your work

After finalizing the 3D models, the students can share their work, either by sharing a link with a limited number of people, or making their designs public on the Tinkercad platform. The 3D model of the Lighthouse of Chania, as shown above, was developed during the testing of this learning resource, and is now available in Tinkercad for all Tinkercad users to view and remix: https://www.tinkercad.com/things/7KVj06mrbPT.

Another option is to create a blog to share the designs of all students and other work done in this project, such as presentations about the monuments, photos of the 3D printed objects, etc. The project results can also be presented in local events, such as school festivals or local exhibitions.

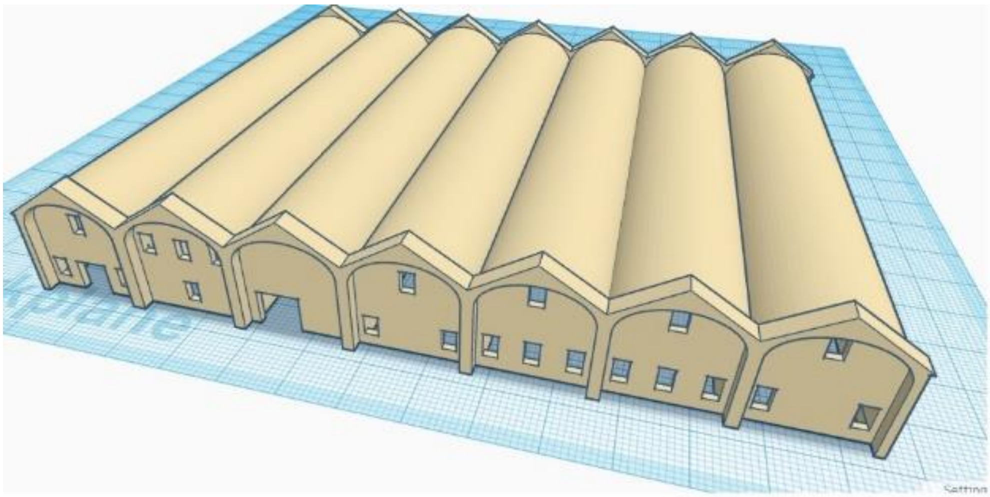
### Step 6. Share your experience with 3D modeling

The students can create a video tutorial to share with others their experience with 3D modeling in Tinkercad. Here is the video we developed in MAKER SCHOOLS for creating a 3D model of the lighthouse of Chania: https://youtu.be/5FBnmpdoURs.

### Designing complex monuments - the Neoria of Chania

We can use the methodology described above to design more complex monuments. First we have to study carefully the object we want to model. What are the basic shapes? Is there a basic pattern that is repeated? We start from a simple model and then we add the details step by step.

A 3D model of the complex monument - the Neoria of Chania – was developed during the testing of the MAKER SCHOOLS learning materials, and is now available in Tinkercad for all Tinkercad users to view and remix: https://www.tinkercad.com/things/lmZ37Jl5ZNQ.



A video tutorial was also developed, showing step by step how to create the 3D model of this monument: https://youtu.be/5FBnmpdoURs.

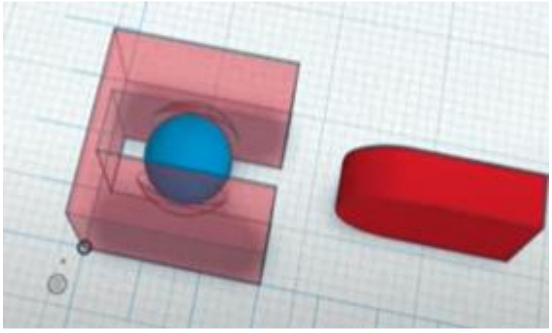
| |
|---|
| Video lessons focused on 3D modelling of the local monuments shown in the activity (image and sound only).<br>Panagiota Mantzarapi (2023). Lighthouse of Chania (3D Design with Tinkercad)<br>https://youtu.be/5FBnmpdoURs<br>Panagiota Mantzarapi (2023). Neoria of Chania (3D Design with Tinkercad)<br>https://youtu.be/4BRN8Am1B-M |

## Part A, Module 4: More complex 3D design and printing

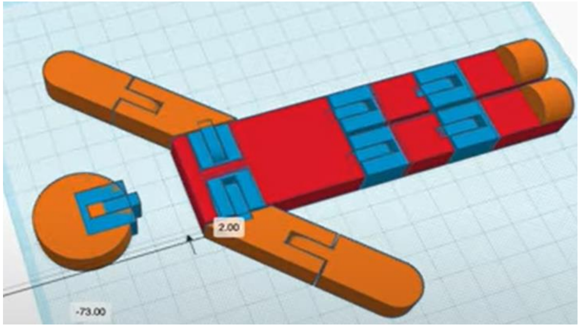
### Activity 4.1: Constructing and printing a single object with hinges

Duration: 40 minutes

The participants watch the video lessons suggested below and learn how to create artefacts with joints. Then they model their own doll or some other object with joints.



*Basic articulation*

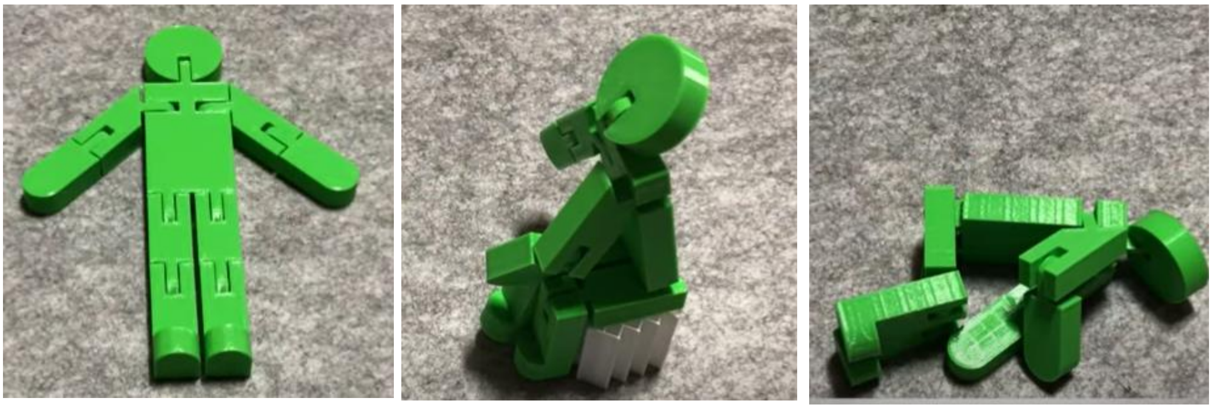



*Doll with joints – 3D model*

Video lessons in English:

1. Eunny (2019) "59) Ball Hinge with Tinkercad + 3D printing | 3D modelling how to make", https://youtu.be/9Y-PZFSOqh4
2. Eunny (2019) "63) Flexible Person with Tinkercad + 3D printing | 3D modelling How to make", https://youtu.be/pngUxiBhnv8and design"

Duration: 13 minutes



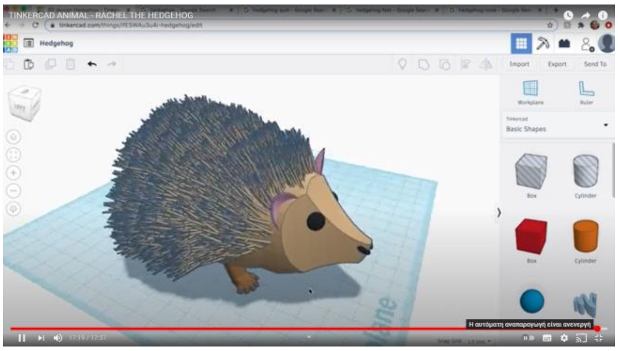
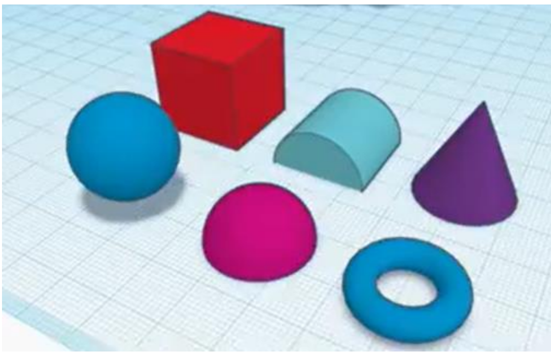
*Doll with joints — 3D Printed Object*

*Source: Eunny (2019) "3D Printed Flexible Person", https://youtu.be/lZ6hjoQNfjc*

# Part B, Module 5: Creative 3D design of organic shapes

## Activity 5.1 Detailed 3D model of an organic object composed of simple shapes

Duration: 3 hours

*Hedgehog produced by processing and deforming simple shapes*

The participants watch the video lesson suggested below. They follow the steps to build a detailed 3D model of a hedgehog using the simple shapes available in Tinkercad's Basic Shapes collection. The video lesson presents design techniques and suggestions for the construction of individual parts of the object such as:

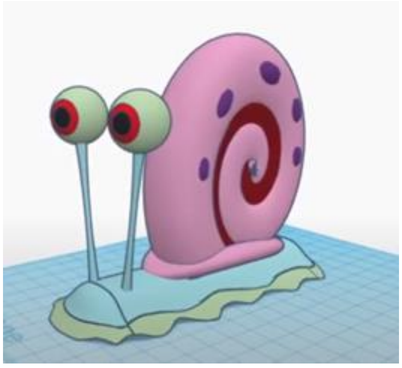
1. Study and analysis of the model we want to create, based on photographs
2. Rotating and resizing of shapes by rotation and changing of size
3. Creation of a symmetric copy using the Mirror command and the ruler
4. Grouping and repeating similar shapes (thorn groups, legs, etc.)
5. Creation of the body from basic shapes (deforming spheres to resemble the desired shape)
6. Creation of thorns from two different cones and construction of a group of thorns with different inclinations in order to achieve a natural-looking result.

The model is quite complex. However, through careful analysis, it can be put together by combining simpler shapes. It can be created by individual participants or by participants working in teams.

| |
|---|
| Video lesson in English: CUG Labs (2020). "Tinker Animal — Rachel the Hedgehog", [https://www.youtube.com/watch?v=a2BGZQ6brMU](https://www.youtube.com/watch?v=a2BGZQ6brMU)<br><br>Duration: 18 minutes |

### Activity 5.2 Organic shapes. Shape generators.

Duration: 3 hours



*Original 2D drawing* *3D model*

The participants will use tools and techniques to build 3D models that do not have a strict geometric form. Some of these tools use Bezier curves. These curves create vector graphics, animation, etc. and are found in popular image processing programs such as Inkscape, Gimp and Photoshop.

Tinkercad has a large collection of Shape Generators that allow us to configure various parameters of a shape

(https://www.engineeringyourstory.com/tinkercad/tinkercad_shape_generators_list.html):

- Corneum (Shape Generators, page 16)
- P-ring (Shape Generators, page 8)
- Extrusion Tool
- The Scrible (Basic Shapes)

| |
|---|
| Video lesson in English: CUG Labs (2020). "Gary the Snail in Tinkercad!", https://www.youtube.com/watch?v=f7XgxPB7wb0<br>Duration: 18 min |

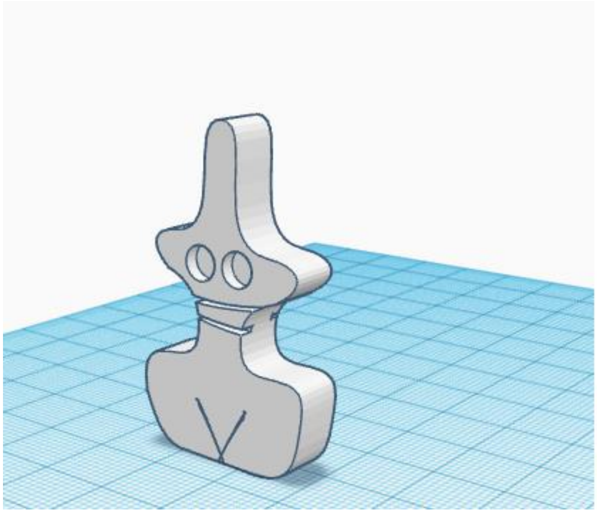
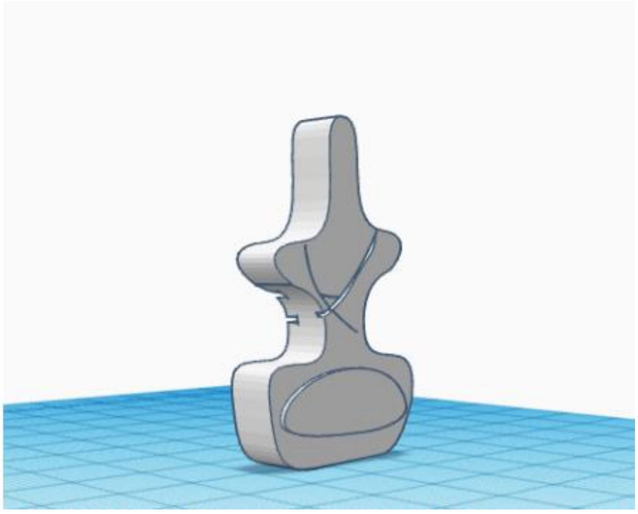
Co-funded by the Erasmus+ Programme of the European Union

### Activity 5.3 Create an original organic shape

The participating teachers apply their skills for designing organic shapes to create their own original 3D design. They explain briefly what their design represents and how they could include it in their classes or in a school activity/project.

Example:

After looking for and studying images of violin-shaped figurines: (e.g. https://cycladic.gr/exhibit/ng0338-violoschimo-idolio) the participants can create their own 3D figurine.

Co-funded by the Erasmus+ Programme of the European Union

## Activity 5.4 Exploring the relationship between modern and ancient art: The Ancient Picasso Project

Duration: 4 hours

**Introduction**

3D design and 3D printing technologies is a powerful tool that can be used in teaching Arts and Art History. Here we focus on an activity in which the students will explore the relationship between ancient and modern art, using the Design Thinking methodology.

In this activity we present a case study: the Ancient Picasso Project. The aim of this project was to explore how Pablo Picasso was influenced by prehistoric Greek art. The teacher can adjust this activity to study the art of another historical era or geographical area and find links with another modern artist, or another art movement.

**Stage 1. Empathize. Is there a relationship between modern and ancient art?**

The students do online research and create a presentation demonstrating the relationship between modern and ancient art. In the Ancient Picasso Project, the students presented their own answers to the following question: *How was Pablo Picasso influenced by Prehistoric Greek Art?*

The students had to present pairs of an ancient artefact and a work of Picasso and explain the relationship between the two: analyze similarities and differences, explain why they think Picasso was fascinated by ancient art and how this affected his work. The students could either do their own research or study the following resources:

1. Wikipedia, Pablo Picasso, https://en.wikipedia.org/wiki/Pablo_Picasso
2. Museum of Cycladic Art, "Picasso and Antiquity. Line and Clay", https://cycladic.gr/en/page/pikaso-kai-archaiotita

- *Clay female figurine, Crete 1400-1300 BC*
- *Clay female figurine, Crete, 1750-1600 BC*
- *Pablo Picasso, The King of Athens*

- *Clay female Figurine, Mycenaean cemetery at Tanagra, 14th century BC*
- *Pablo Picasso, Standing woman, Vallauris, 1947*

**Stage 2. Define. How can we creatively explore the relationship of modern and ancient art?**

The students are asked to find ways to creatively explore the relationship between modern and ancient art. In the Ancient Picasso Project we carried out, the aim was to create original works of art, in order to develop a deeper understanding of the artist and his influences, and also to feel creative, imaginative and able to inspire others.

**Stage 3. Ideate. What exactly are we going to create?**

The students have to come up with specific ideas. They are encouraged to generate as many ideas as possible. Then they discuss their ideas and select the ones they will implement, possibly after improving them. The students can use paper or modelling clay to present and share their ideas.

In the Ancient Picasso Project the students decided to create mini sculptures inspired from ancient Cycladic Art and the cubist works of Pablo Picasso. The students used color paper and modelling clay to present and share their ideas (see the photos to the right).

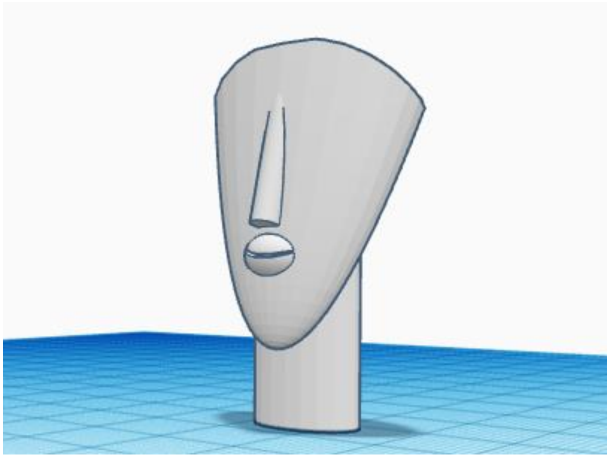
In this project the following resources can be used to explain cubism and its relation with ancient art:

1. Wikipedia, Cubist sculpture, https://en.wikipedia.org/wiki/Cubist_sculpture
2. Curious Muse. Cubism in 9 Minutes: Art Movement by Pablo Picasso Explained. https://www.youtube.com/watch?v=IF-nmwm7-Bg

**Stage 4. Prototyping. Creating and sharing 3D Designs**

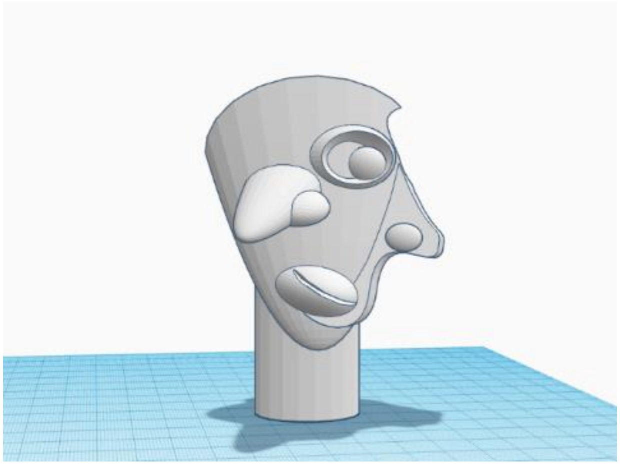
The students create their own 3D designs using Tinkercad or another suitable software.

In the Ancient Picasso Project the teacher showed the students how to create their own version of a head inspired by Cycladic Art. The students were then encouraged to modify the head inspired by Picasso's style and his cubistic sculptures and portraits. You can see one of the results below.



*Cycladic-like head*

*https://www.tinkercad.com/things/kyyjsnHFG3E*



*Ancient Picasso Head*

*https://www.tinkercad.com/things/aq9k5tKMJ1d*

**Stage 5. Testing**

## Presentation of the project results

After creating their designs the students can decide if they want to keep their designs private, share them with others, or make them public so that anyone using the Tinkercad platform can view, comment and remix. Another option is to create a blog and display all the project results online (presentations and 3D designs). The 3D designs can also be printed, in various sizes using a 3D printer, and the mini sculptures can be exhibited during a school event. You can see some of the printed models created by students in the Ancient Picasso Project.

*Cycladic-like head, 3D printed in two sizes*

*Ancient Picasso Head, 3D printed mini sculpture*

## Feedback collection

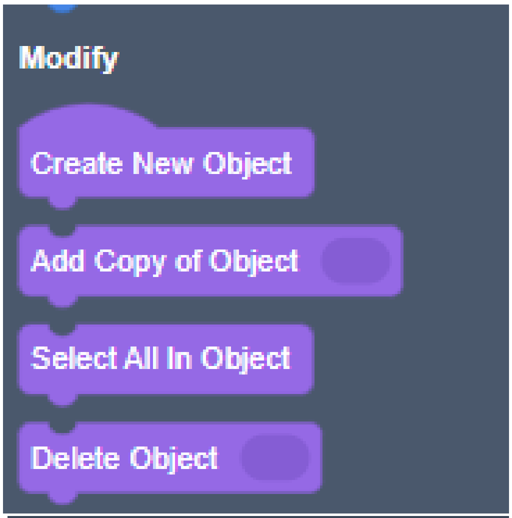
In either case (online or onsite presentation) the students can collect feedback, using a guest book or a questionnaire. They should seek to learn: what people liked, what can be improved or what other ideas for future projects are there.

In the Ancient Picasso Project some of the 3D designs were made public in the Tinkercad Platform and were printed using a 3D printer.

Co-funded by the Erasmus+ Programme of the European Union

# Part B, Module 6: 3D design using programming techniques

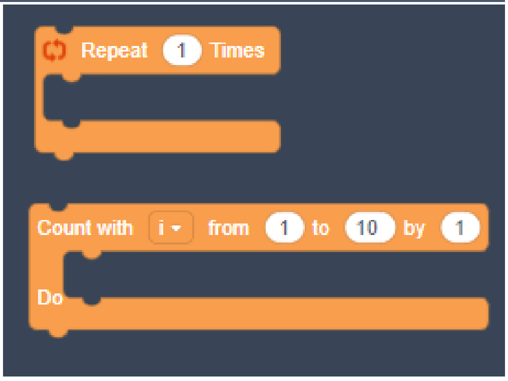
## The Codeblocks environment




With Codeblocks we can create 3D designs using simple programming techniques. The design is done like a computer program, which makes it particularly easy to correct and modify. Furthermore, having created our design as a computer program we have accurately described the process of creating it.

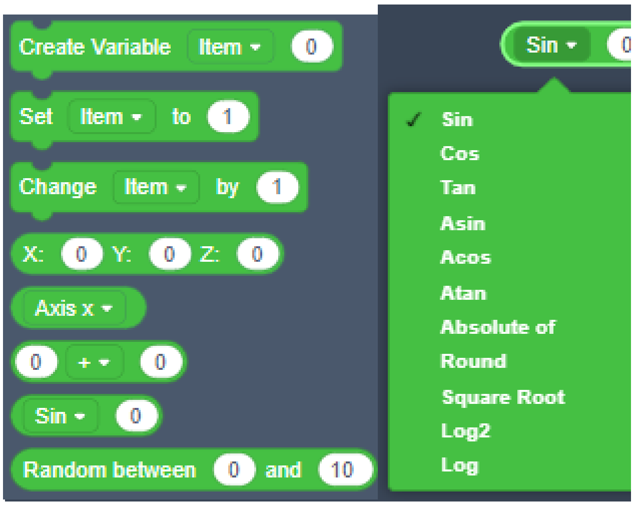
The Codeblocks environment has:

- The collection of basic shapes of Tinkercad (except the Scribble tool).
- Basic commands for handling and transforming a shape (move, rotate, scale, change colour, copy and delete)
- Grouping of objects

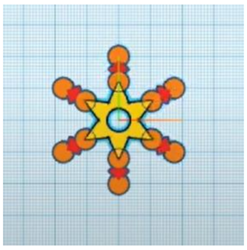



In addition, the Codeblocks environment has:

- **Objects -** we can create new objects, and then use them in our design (Add Copy of Object) by organising our design into hierarchical structures.
- **Variables -** we can create variables and attribute to them numerical values (Create Variable, Set Item to, Change Item by).
- **Mathematical operations and functions:** We can perform mathematical calculations using basic arithmetic operations (+,-,*,/), a random number generator and a small set of functions.
- **Iterative (looping) structures (Repeat, Count with)**: allow us to create identical or differentiated copies of an object by appropriately changing the values of the variables in each iteration.



## Activity 6.1 Create a simple design with Codeblocks



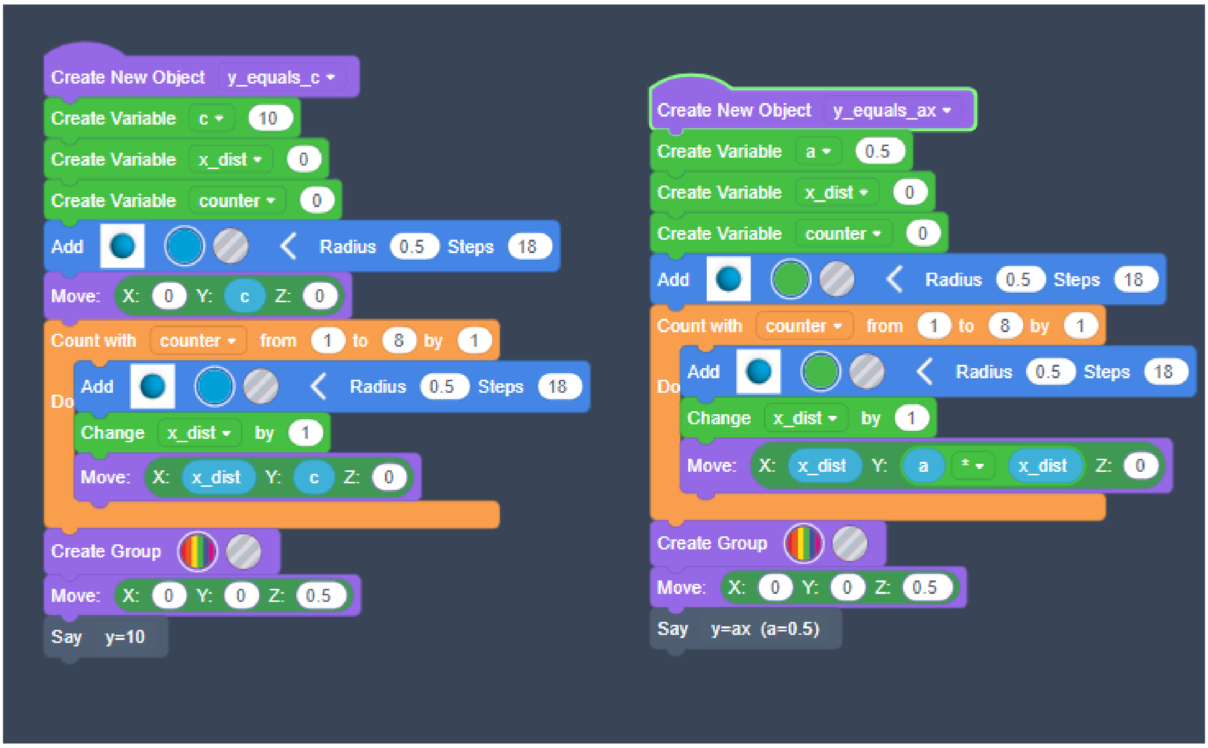
The participants watch the video suggested below. This exercise covers the following functions: using and customising basic shapes, adding a hole, grouping, object creation, iterative structure (Repeat); exporting the design as .svg for printing.

The participants follow the proposed procedure to design their own snowflake with coding.

| |
|---|
| Video lesson in English: Oxford Science (2019). Design a Snowflake using Tinkercad Codeblocks, [https://youtu.be/_FlYI9AbDaE?list=LL](https://youtu.be/_FlYI9AbDaE?list=LL)<br>Duration 13.5 minutes |

## Activity 6.2 Representation of mathematical relationships

The participants can learn to create 3D shapes or sequences of shapes that are described by mathematical relationships, by using mathematical calculations to define the position and form of 3D objects. For example, in the code below, the positions of the spheres are calculated from the functions y=c and y=ax (z=0).




*Code for representation of linear functions y=c, y=ax*

Participants can also study a different approach to representing mathematical relationships with the Codeblocks environment in the video suggested below.

| |
|---|
| Video lesson in English: Rob Morrill (2020). Codeblocks Math, [https://youtu.be/-XE5cCg_9wo?list=LL](https://youtu.be/-XE5cCg_9wo?list=LL)<br>Duration: 3 minutes |

Co-funded by the Erasmus+ Programme of the European Union

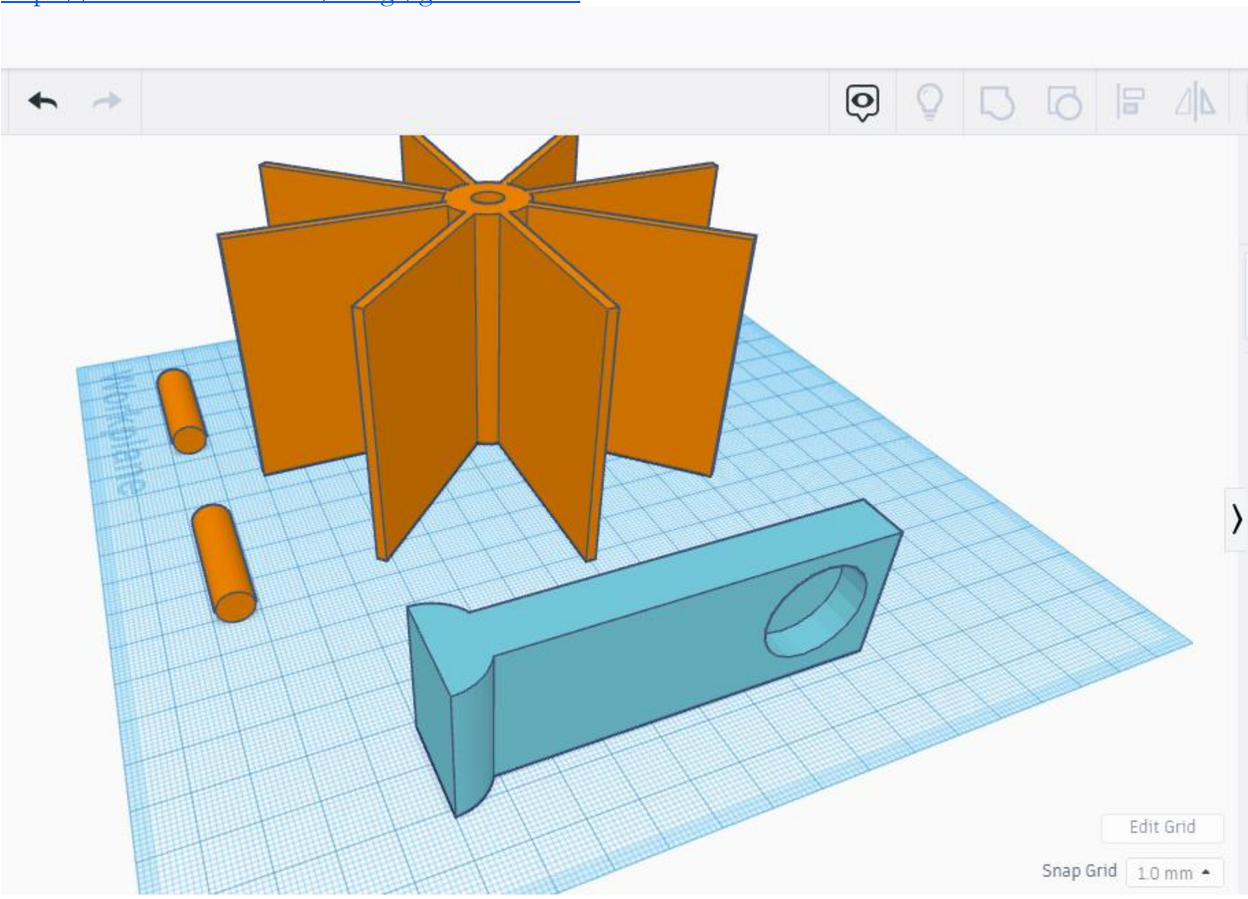
## Part C, Module 7: 3D printing in practice

A 3D design created in a program such as Tinkercad can usually be printed with a 3D printer. However, the process is not always easy or obvious as the design may contain parts that cannot be printed without additional steps, e.g. by adding supporting structures. The following guide provides some basic printing instructions (with the help of a template) for successful printing on a Creality 3D Ender Pro printer.

### The design

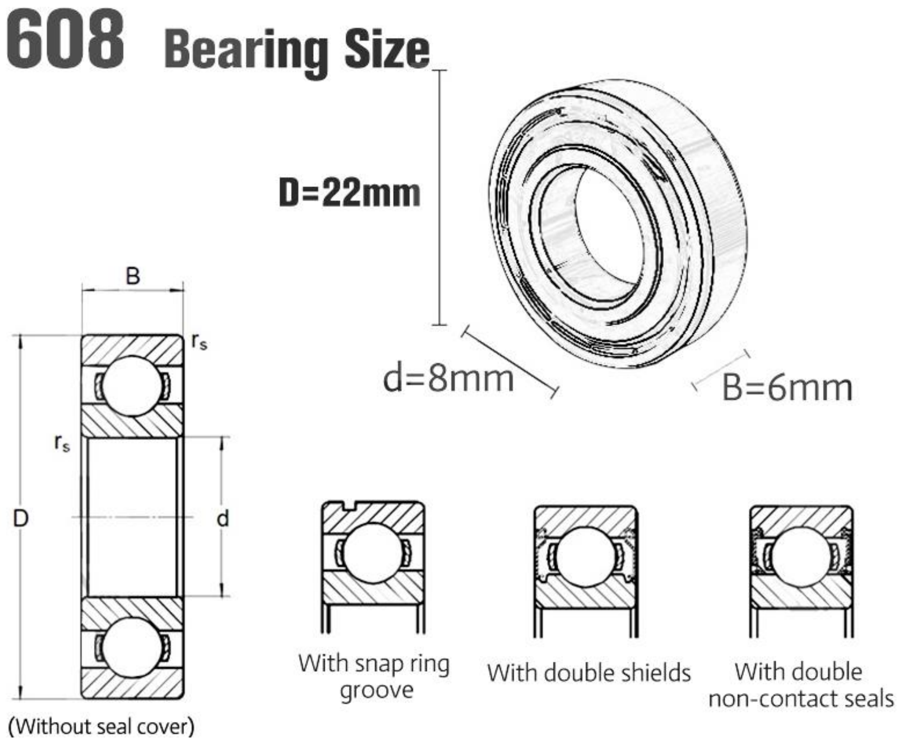
We will be printing the design found here:

https://www.tinkercad.com/things/g3oIvYI28ZR




It is a simple watermill consisting of a wheel (turbine), two side stands (the same piece printed twice) and two tube-like pieces that will form the axle shaft of the wheel. It should be noted that the base is intended to accommodate two Type 608 bearings in which the axle shaft is fitted.

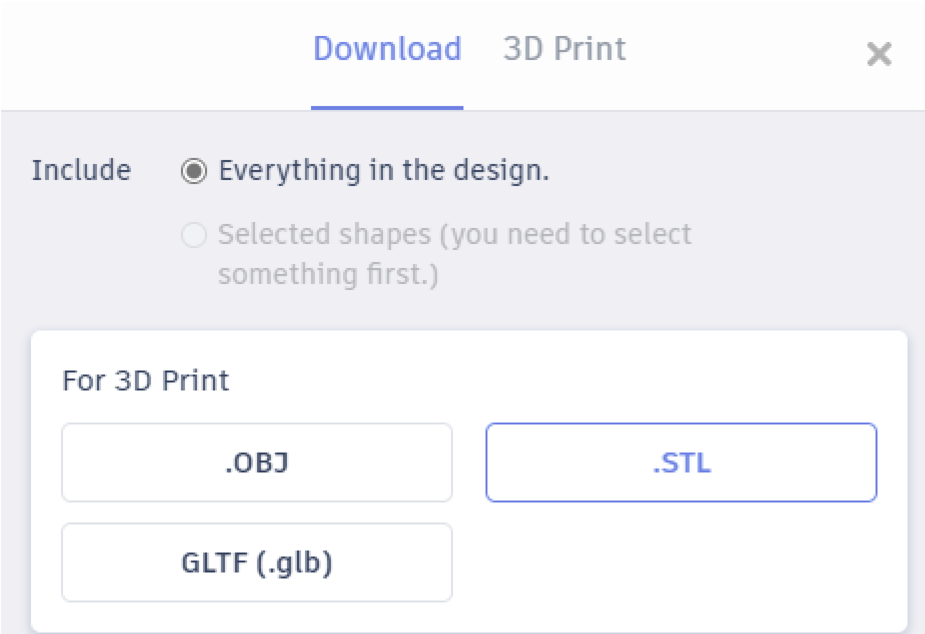
The bearing is a standard 608 type and is shown below:




The main dimensions are: diameter 22 mm, depth 6 mm, inner diameter 8 mm. These dimensions should be taken into account in order to adapt the bases and the shaft to the bearing.

## Printing preparation

To prepare our print design, the first step is to extract it from Tinkercad. For this purpose we create an .STL file from the export option:




We can choose either to export all shapes or only the selected one. If we export them all, we can print them at the same time (if they would fit on the 3D printer bed). On the other hand, this approach risks spoiling the entire printing if one of the pieces fails (e.g. comes loose from the table). It is usually safer to print the different parts separately.

Before printing, the printer bed should be levelled. This process differs from printer to printer but is usually carried out by moving the printer head to the 4 corners of the bed and rotating the bed regulators so that the head-bed clearance is about 0.5 mm (as much as to fit a A4 page). This procedure is usually described in detail in the printer's instruction manual.

Printing only one piece at a time has the advantage of printing in the central part of the bed, which is usually the one adjusted most correctly and flat.

In our example, printing is done piece by piece, and the shapes are extracted into different files.

## The slicing process

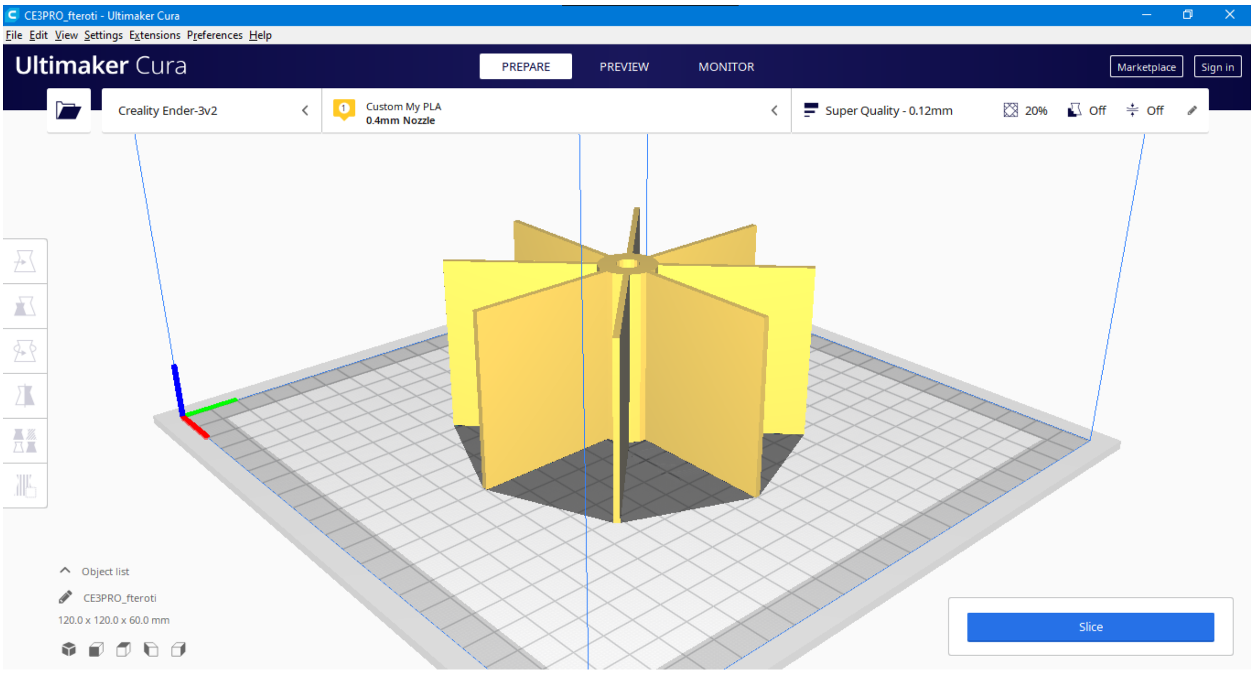
Before we print our file, we need to perform *slicing*. Slicing takes the original .STL file and converts it into a series of printing instructions, suitable for our own 3D printer. During slicing we will set yet another set of parameters such as:

- The printing quality
- The type of material
- The temperatures of the material (printer nozzle) and the bed
- Addition of support structures and adhesion.

There are several slicing programs, but the most popular is Cura which is free. It supports many printers including our model. Cura is created by Ultimaker and you can download it here: [Ultimaker Cura: Powerful, easy-to-use 3D printing software]

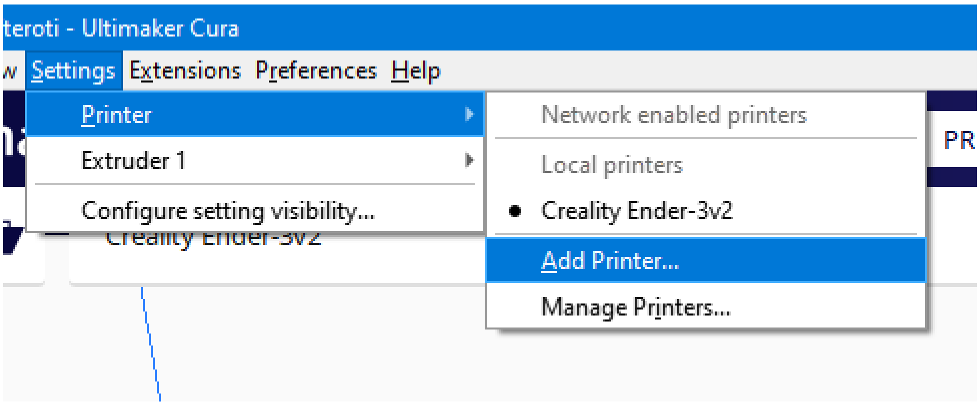
Opening the model in Cura is done by selecting File ➔ Open Files...

The shape of the wheel after opening the file is shown below:

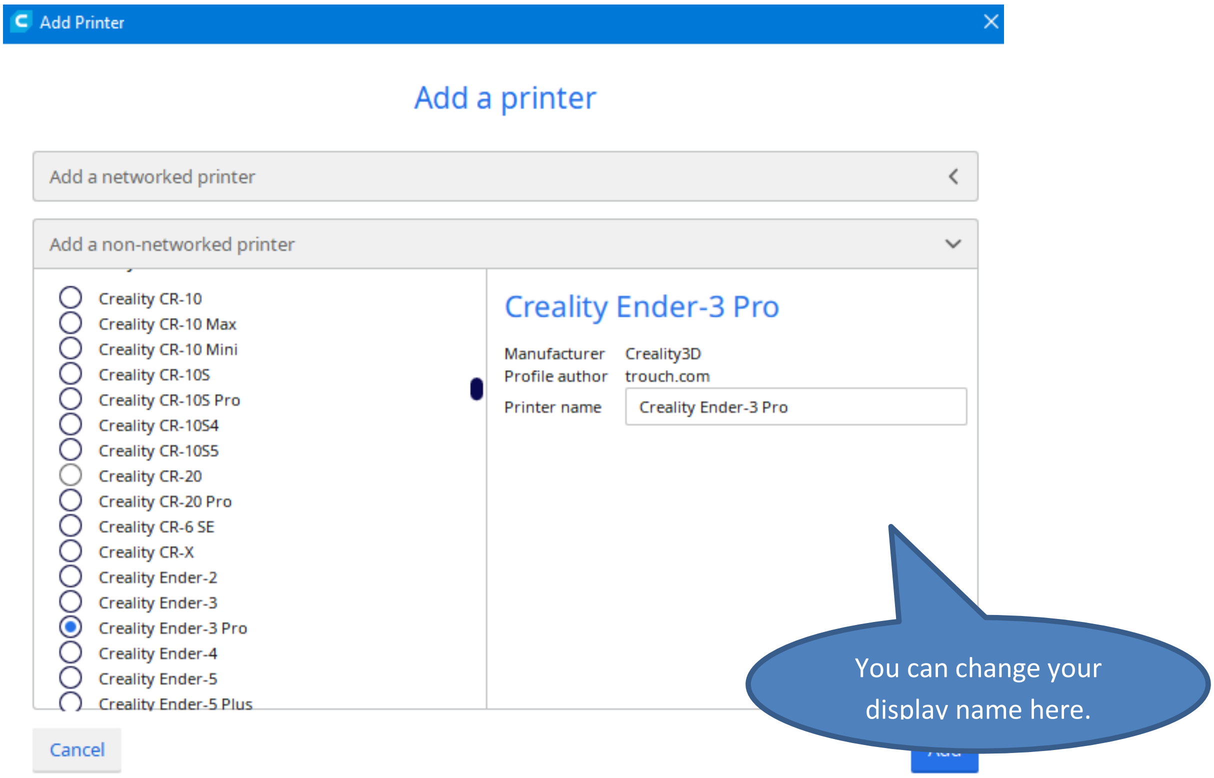



Before we start the slicing process, we need to look and adjust the settings.

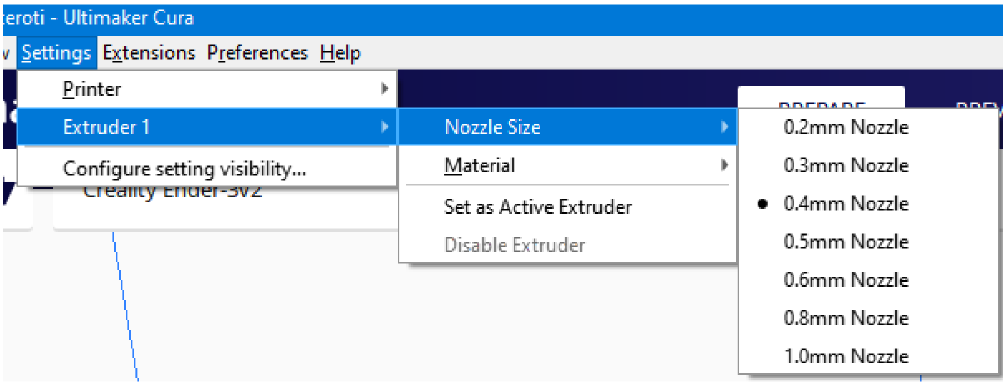
The first step is to add the printer:




We will select Creality from the list and select 3D Ender-Pro as a printer. The 3D Ender V2 is not on the list, but it is compatible with the 3D Ender-Pro. In the Printer Name field we can change the name to Creality Ender 3D v2.




After adding the printer, we need to check the size of the nozzle:



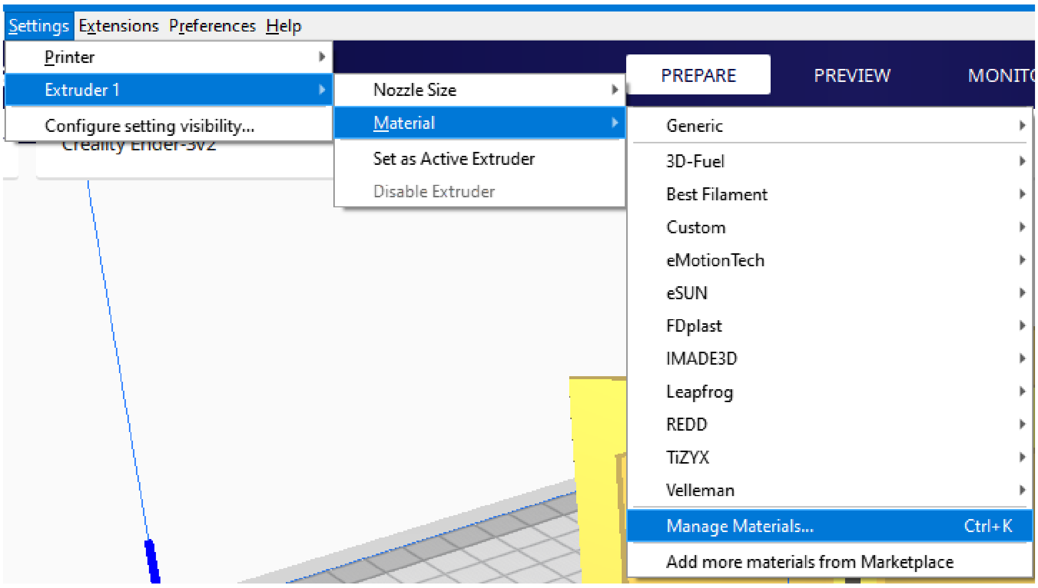
For our printer, the standard preinstalled size is 0.4 mm.

The next step is to choose the type and brand of material we will use, if it is among those preinstalled in Cura settings. If we use a material that does not exist in the Cura settings, we can choose Generic. We need to know key elements of the material such as:

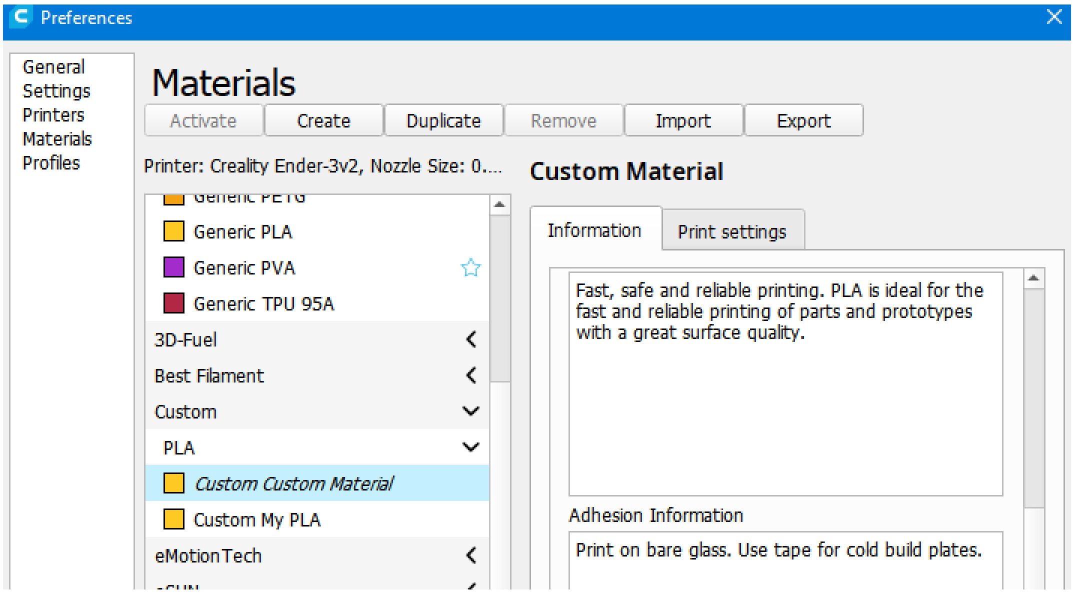
- The type of material, e.g. PLA, ABS, etc.
- Suggested nozzle (melting) and bed temperatures

PLA usually requires a melting temperature of 200 degrees Celsius and a bed temperature of 60 degrees. The heating of the bed is important in order for our print to stick firmly to the bed while printing.

The material we will use for this print is PLA. We choose Generic, so that we can configure it as a new material:



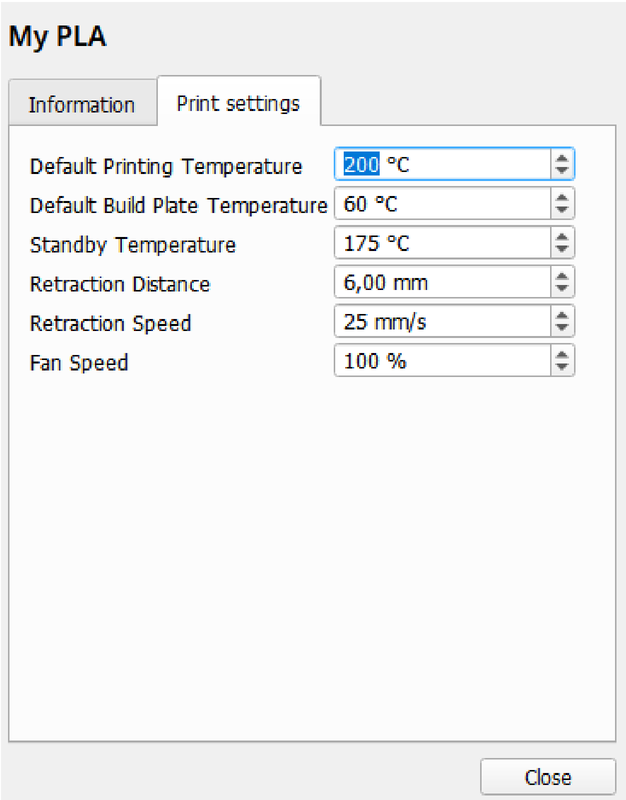

We can create our own material in the Materials ➔ Create selection:

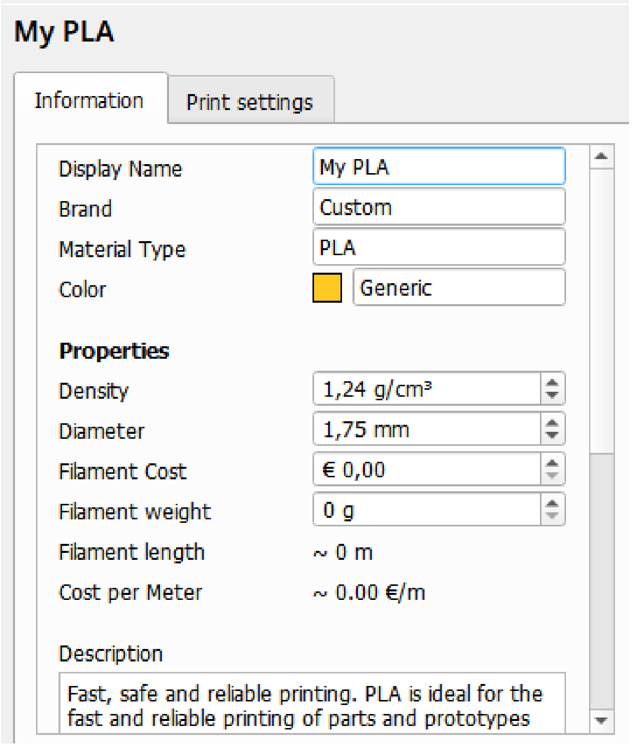



Below are the recommended settings for PLA and this printer:

Co-funded by the Erasmus+ Programme of the European Union

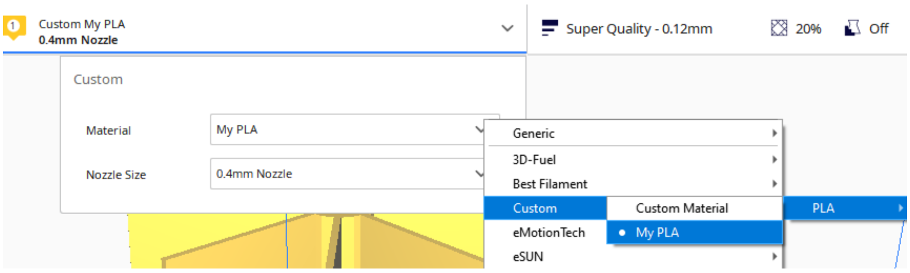
*The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*



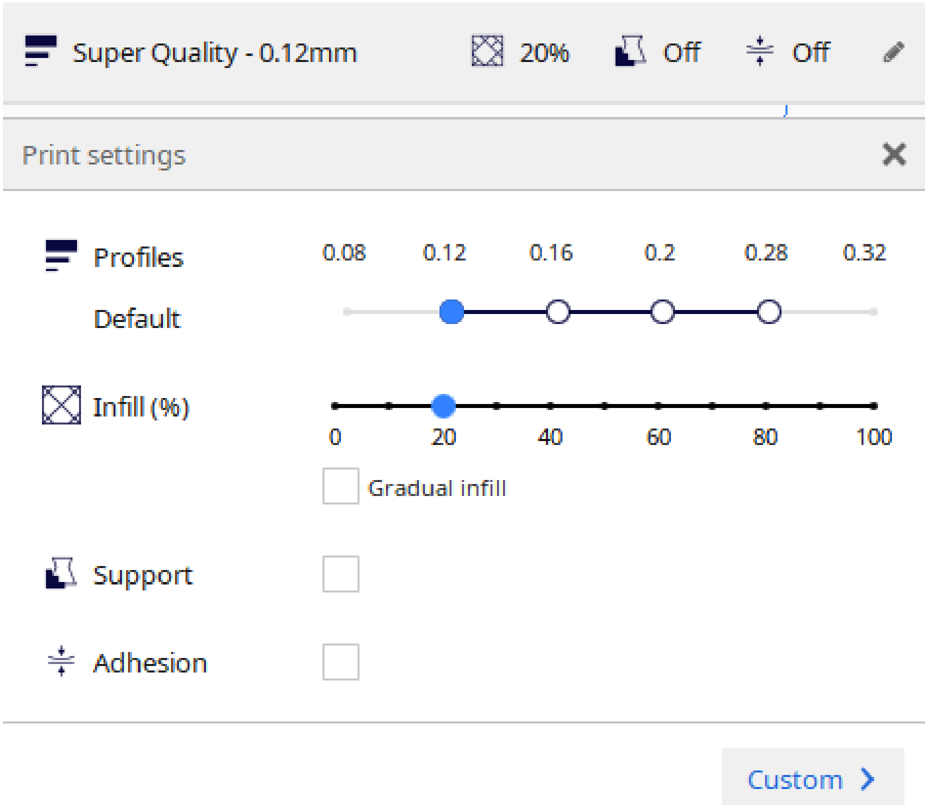




Having created our material, we need to select it for the printing job:

Co-funded by the
Erasmus+ Programme
of the European Union



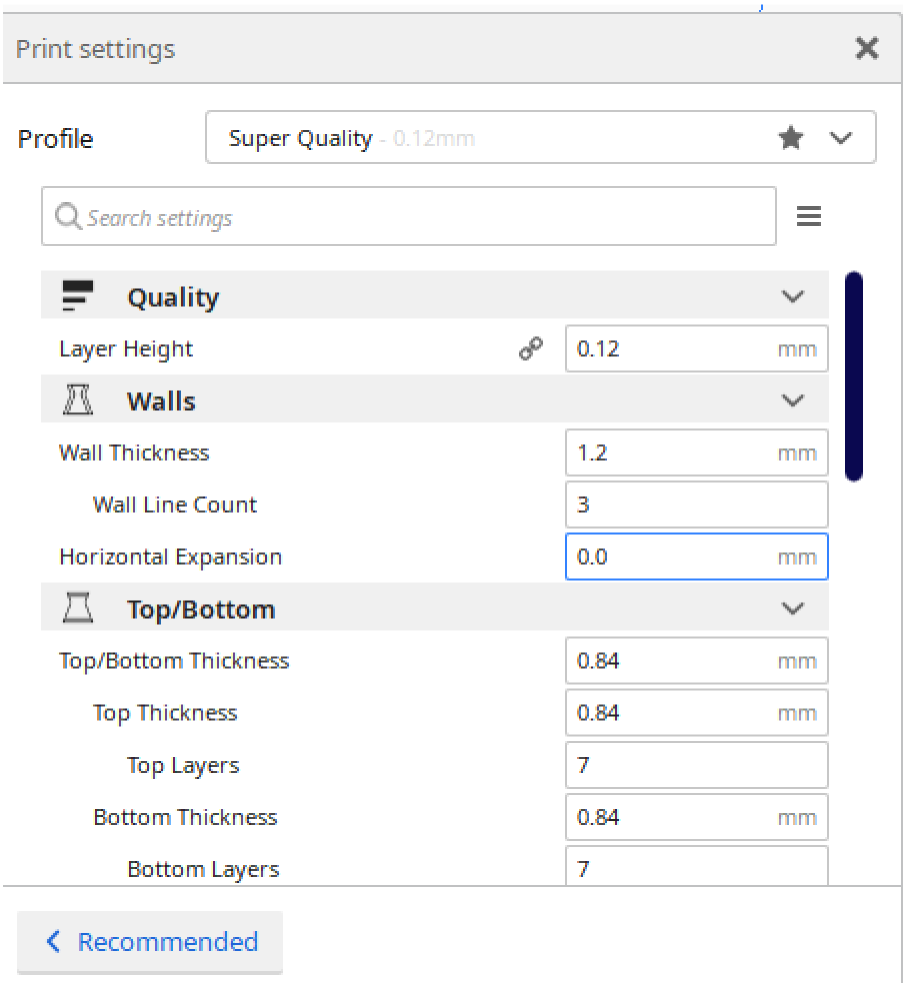

Before we start Slicing, we should also look at the printing parameters:




For the best print quality, we select the lowest possible value in profiles. However, this dramatically increases the printing time and possibly the amount of material that will be used.

Infill is a setting that allows us to determine how solid our object will be. For economy of material, the solid parts do not need to be fully filled but can be filled up to the percentage we specify. If for some reason we want to make the object more resilient, we can increase that percentage. 20% is generally acceptable.

If we want to define the settings more accurately, we can use the Custom option:




Two more options we can use are Support and Adhesion:


*Support* is used if some parts of our design are hanging and cannot be printed on their own without some support.

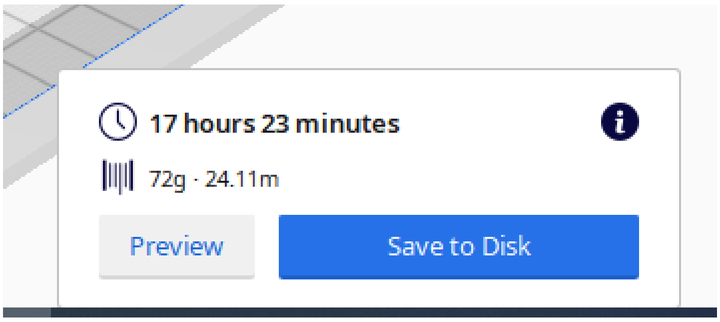
*Adhesion* is used to help our printing (the original layers) stick to the printer bed more effectively. This is especially important if the base of the shape we print is small or not smooth.

In our models, neither option is necessary.

After we complete the settings, we select the ***Slice*** command. The program will show us an estimate of the time and material that will be needed:

Co-funded by the Erasmus+ Programme of the European Union

*The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*




We select “Save to Disk” to store the produced **.gcode** file on our disk, and transfer it to the SD card of the printer. If we have a USB Flash drive connected, the program allows us to save directly to it. Then we need to insert the card to the printer and follow the instructions to start the printing.

In 3D Ender v2 we can do the following:

Prepare ➔ Preheat PLA

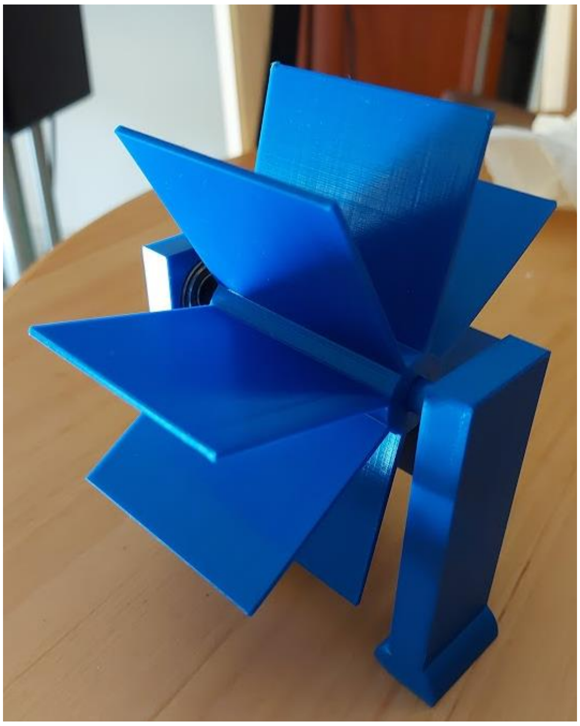
Then we select ➔ Print and point to the .gcode file we created.

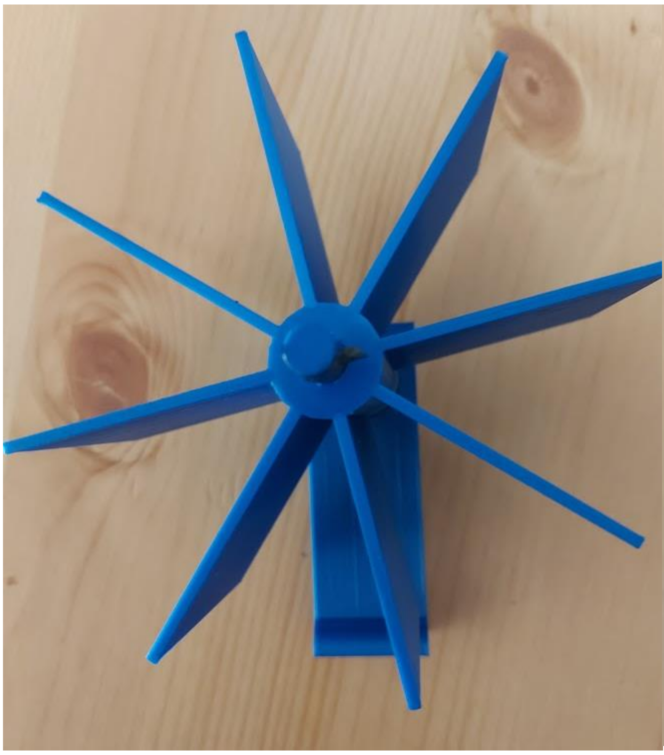
## Print result

For successful printing of the parts, the following adaptations may need to be made:

- The shaft has a diameter of 7.95 mm, while the hole in the wheel is 8 mm. This small difference is necessary in order to allow the shaft to be fitted into the wheel. The holes in 3D printing are usually less accurate than solid objects.
- For the bearing, the above adjustment of the shaft is not optimal. The shaft should have a diameter of exactly 8 mm as the bearing is constructed with high precision. For better adjustment, the shaft should be made with a slightly different diameter at both ends (slightly telescopic).
- The mounting sockets for the bearings to the bases are slightly larger than the diameter of the bearings: 22.2 mm. The bearings will be pressed into the bases and need to be forced in. Depending on the printing material, the difference in diameter can be lower. For example, for printing with ABS (higher elasticity) the hole could be 22.1 mm.

The final result of the printing is shown below:





Co-funded by the
Erasmus+ Programme
of the European Union

# Internet Sources


## Class management in Tinkercad and personal data

Autodesk Tinkercad Privacy and Security. https://www.tinkercad.com/privacy

Official Guide to Tinkercad Classrooms. https://www.tinkercad.com/blog/official-guide-to-tinkercad-classrooms

Graduating Students from Classrooms. https://www.tinkercad.com/blog/graduating-students-from-classrooms

## Basic concepts of 3D design

JessyRatfink.(2020). Learn to Speak Tinkercad. https://blog.tinkercad.com/learn-to-speak-tinkercad

3D Modeling and Design Glossary — Beginner. https://content.instructables.com/ORIG/FQ2/HOTN/J8AGQT3N/FQ2HOTNJ8AGQT3N.pdf

## Keyboard shortcuts

Keyboard Shortcuts for the 3D Editor. https://www.tinkercad.com/blog/keyboard-shortcuts-for-the-3d-editor

Brochure with Tinkercad keyboard shortcuts. https://blogdottinkercaddotcom.files.wordpress.com/2018/08/tinkercad-keyboard-shortcuts_revised-8-31-182.pdf

Jumekubo4edu. 2020. “20. New Tinkercad — Single Key Shortcuts”. https://www.youtube.com/watch?v=OQASWHYtg1M


Co-funded by the Erasmus+ Programme of the European Union