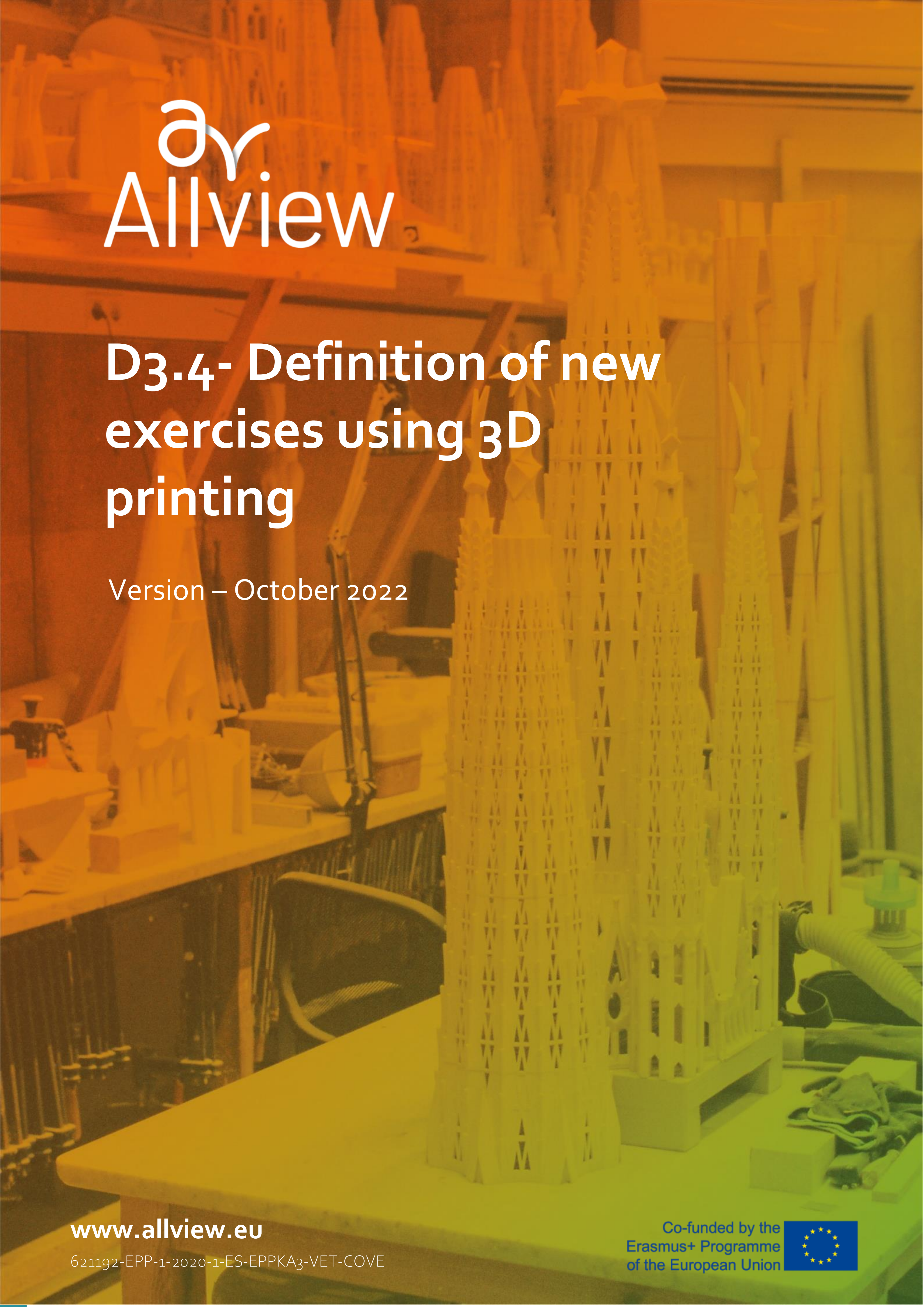

Allview

D3.4- Definition of new exercises using 3D printing

Version – October 2022

www.allview.eu

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The ALLVIEW project is a new transnational cooperation platform that connects Centres of Vocational Excellence (CoVEs) within the wood and furniture sector. ALLVIEW has operational objectives on a regional, national, and European level which aim at an innovative approach to modernising vocational education and training.

Allview

1

Introduction

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1. Introduction

This document reports the first results performed in task **“T3.4: 3D printing set of exercises”** in the framework of the **WP3 “KET kit for training in the F&W sector”.**

One of the objectives of this work package is to research new teaching methods based on the project approach and in which students and teachers use Industry 4.0 technologies as enablers in the classroom. In the field of education, the use of technologies such as 3D printing improves performance, the learning process, the development of skills and a greater engagement of students and teachers with the subject matter. In addition, 3D printing stimulates creativity and collaborative problem solving.

As a result of this task, 14 exercises on 3D printing have been defined. The set of 3D printing exercises will allow students to reinforce concepts related to wood and furniture but will also serve to introduce them to the world of 3D printing itself. This is very important, as additive manufacturing has proven to be a mainstay in the furniture and wood sector.

The procedure followed by the consortium in carrying out this task was as follows:

→ Creation of a template to define the exercise at three levels: description of the idea and model, graphic definition of the exercise, and specifications for its use in the classroom.

→ Identification of subjects or topics mainly related to the furniture and wood sector for which exercises would be created.

→ Identification and description of the exercises on a theoretical, graphic, and educational level following the template.

This document contains the work carried out in the first phase of this activity, which corresponds to the identification and definition of the 3D exercises.

First, a generic introduction is given on the exercises identified, the methodologies for their insertion in the classroom and the main learning outcomes and benefits that the students will obtain through this technology and these exercises. After this, some conclusions are established as a connection with the next phase of this activity and WP3, where these exercises will be designed, printed, and tested. The report concludes with a detailed description of each of the 14 exercises identified for this task.

Allview

2

3D Printing set of exercises.

Defined Exercises.

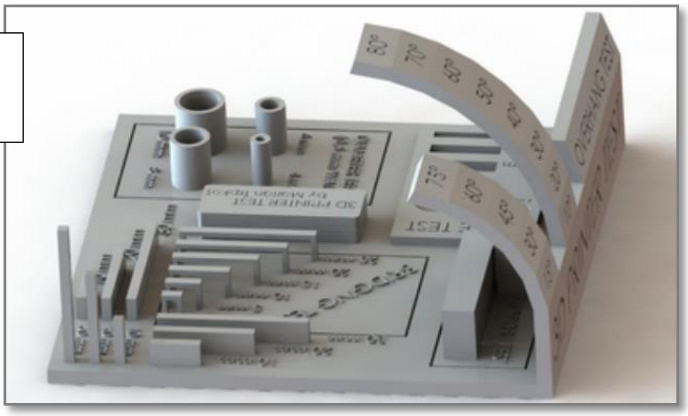
2. Identified exercises, methodologies, and main learning outcomes.

Identified exercises

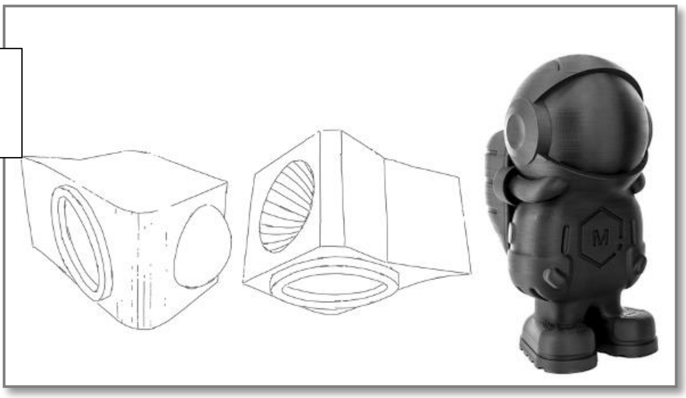
For the task T3.4 "3D printing set of exercises", 14 exercises have been defined, structured in such a way that the acquisition of knowledge is gradual. The first two exercises are intended to immerse the student in 3D printing by gaining knowledge about parameters, surface finishing, printing problem solving and materials. The following 3 exercises provide the student with the necessary knowledge on how to creatively model a complex part of small dimensions and scale it to the required dimensions, as well as acquire skills on how to model moving parts and how to orient the parts to save support material. Other two exercises have been designed. They focus on the creation of furniture prototypes with additive manufacturing and the design of complex geometries in furniture design. Moreover, there are five exercises focused on the integration of 3D printing in the design, manufacture, and repair of furniture. The concept of "hybrid technology", in which traditional and additive manufacturing merge, will be explored by the student. He/she will discover the advantages and possibilities of integrating this technology in the production of furniture by learning by doing. Following on from the previous ones, there is an exercise designed to encourage the student to think about adapting the product to different customers or to follow standard requirements related to ergonomics, dimensions, and safety requirements. Finally, in order to create synergy with WP4 "Corporate Social Responsibility", an exercise has been defined to facilitate people with cognitive disabilities to create geometric shapes with wood. This exercise will enable the disabled person to draw and carve flat geometric shapes, allowing them to recognise shapes, perimeters, and areas much more easily.

The complete definition of all exercises, together with their teaching specifications and technical specifications can be found in section 4 "3D Printing set of exercises. Defined Exercises." Names and descriptive images of the 14 exercises are enumerated here:

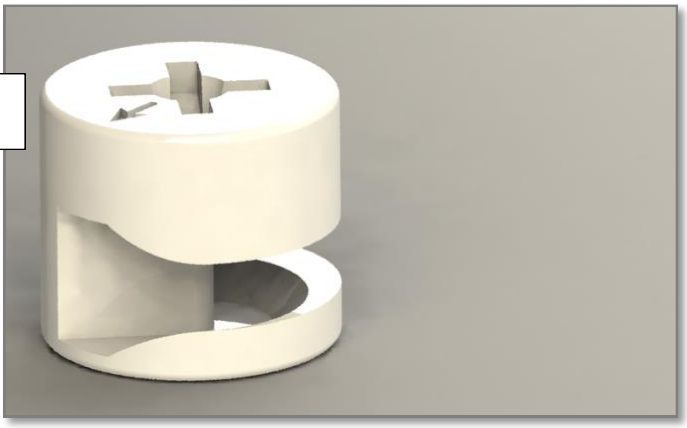
Exercise 1: Setting up a 3D printer for printing dedicated to the furniture



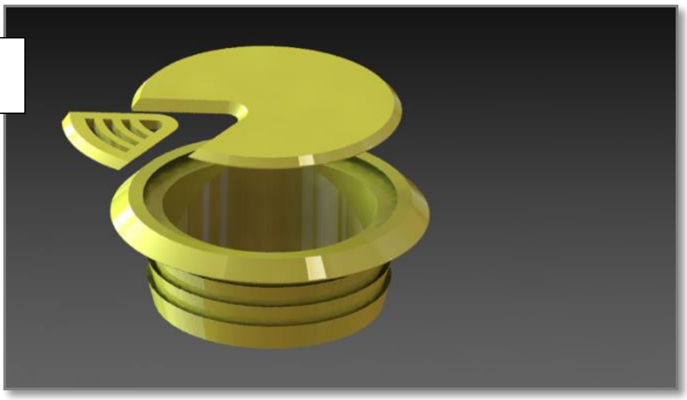
Exercise 2: Materials and finishing dedicated to 3D printing (FDM)



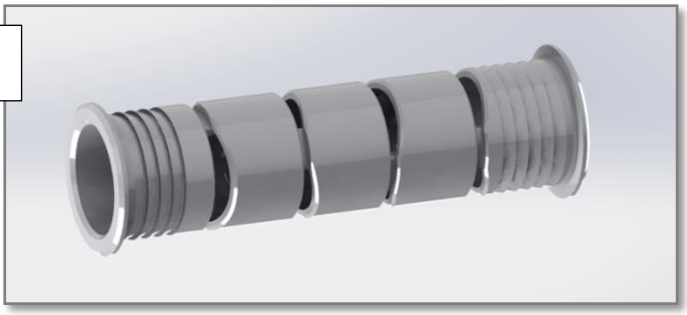
Exercise 3: Eccentric connector



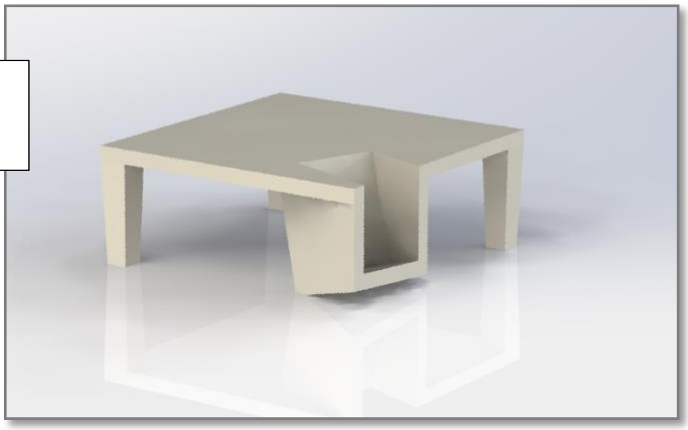
Exercise 4: Cable grommet



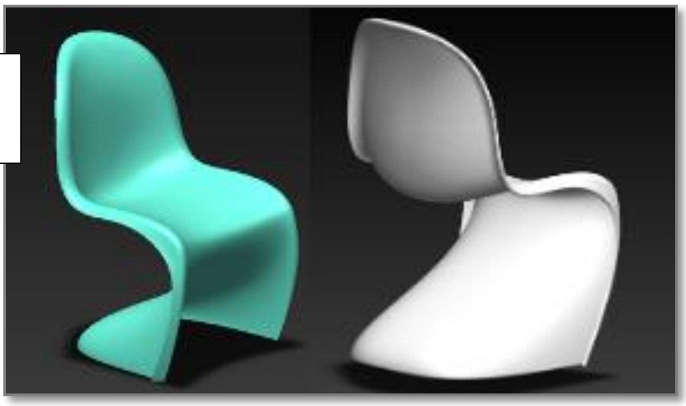
Exercise 5: Cable route



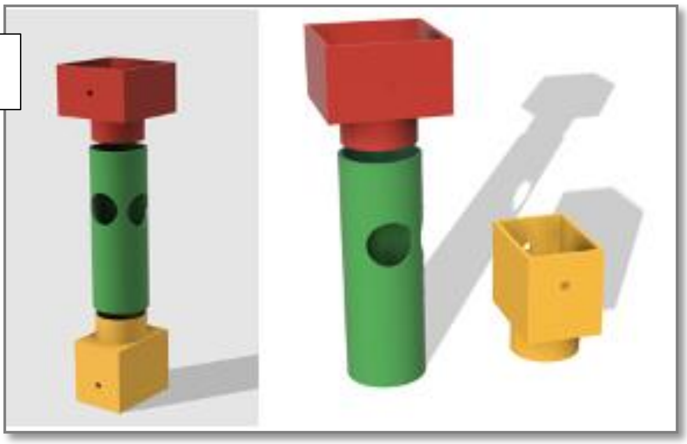
Exercise 6: Prototyping in 3D printing



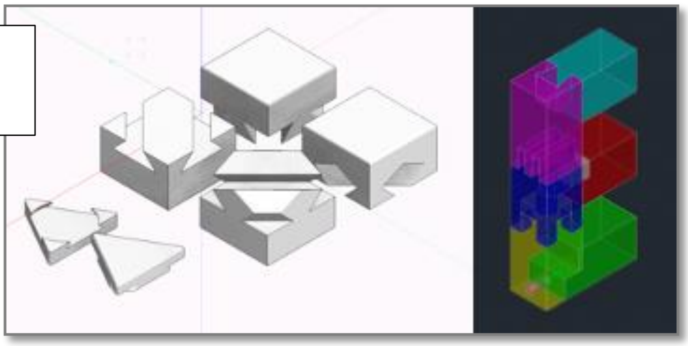
Exercise 7: Design of furniture with complex geometry in 3D printing



Exercise 8: Chair repair connectors

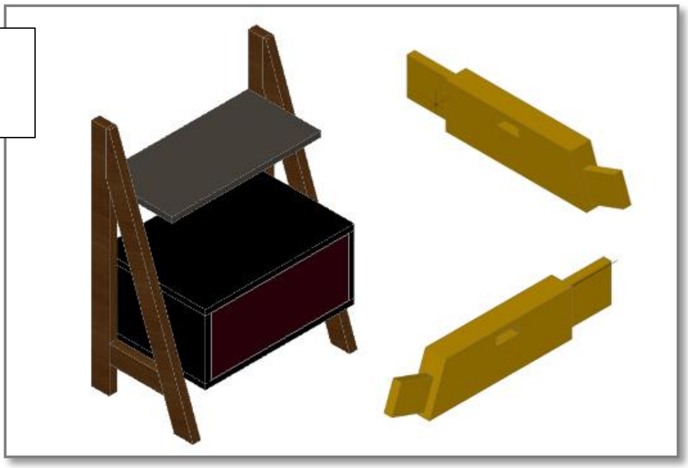


Exercise 9: Assembled Pieces for furniture design

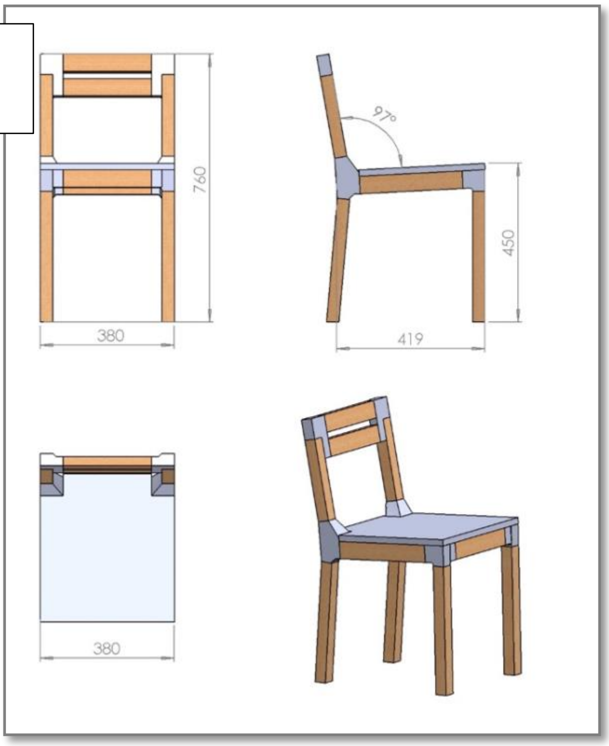


Exercise 10: Furniture design with 3D printed connectors

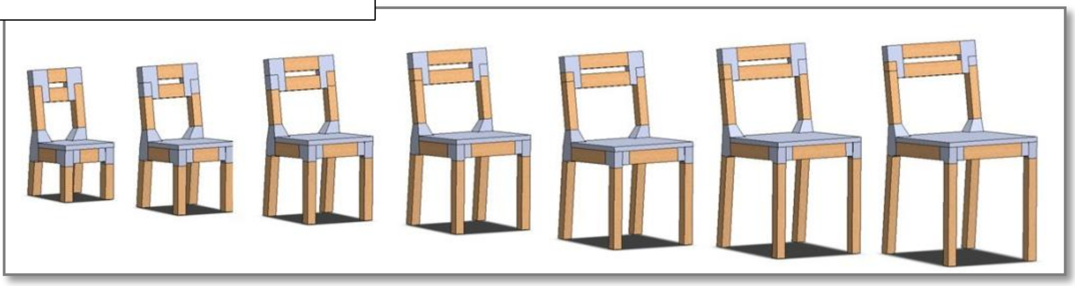
Exercise 11: Furniture design with 3D printed parts



Exercise 12: F Chair design with 3D printed connectors and simple wooden elements



Exercise 13: School chair design for different age of kids



Exercise 14: Technical drawing and wood workshop for the disabled people

Methodology for inclusion in the classroom and main Learning Outcomes.

The methodology best suited to integrating these exercises into the classroom and the curriculum is project-based learning (PBL).

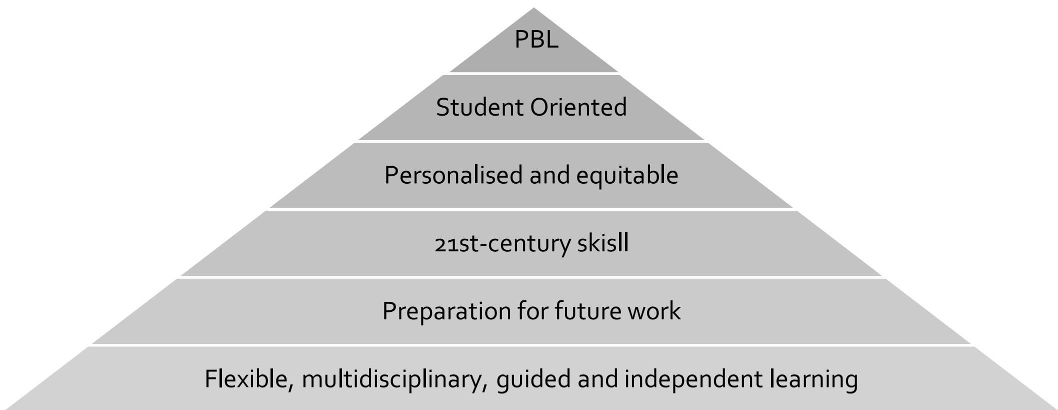
Project-based learning is a teaching method that encourages learning through active participation in real-world, personally meaningful, or engaging projects.

Students typically work on a project over an extended period (one to several weeks) that leads them to solve a real-world problem, answer a complex question and design their best solution. They then demonstrate what they have learned by creating a public product or presentation for a real audience (classmates and teachers).

By working in this way, project-based learning allows students to develop deep content knowledge, as well as 21st-century skills such as active learning, critical thinking, collaboration and cooperation, creativity, problem solving and communication. PBL is also known to unleash a contagious creative energy between students and teachers, leading to greater student engagement and improved learning outcomes for all. [1]

The transversal outcomes of project-based learning that are intended to be achieved by carrying out these exercises on additive manufacturing may vary according to the school, the teacher and the type of project being carried out. The main ones are:

- ⇒ Integration of knowledge.
- ⇒ Fostering autonomous learning through independent investigation of unstructured problems.
- ⇒ Teamwork, which helps prepare students for a social environment.
- ⇒ Self-assessment and self-criticism, which encourages students to look beyond their own ideas and knowledge.

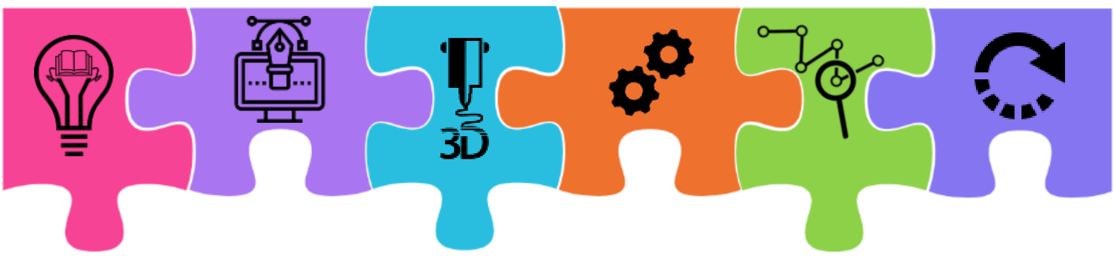


Graphic 1: Characteristics of project-based learning.

Benefits of Project Based Learning:

- Presents opportunities for deeper learning in context and for the development of important skills relating to college and career readiness.
- Boosts student engagement and achievement and helps students develop the 21st-century skills they need to succeed in their future careers. These include critical thinking, communication, collaboration, and creativity, among others.
- Makes room for student choice, allowing students to feel like architects of their own learning journey.
- Improves student attitudes toward education, thanks to its ability to keep students engaged.
- Provides plenty of opportunities for feedback and revision of the plan and the project
- Encourages students to make meaningful connections across content areas, rather than thinking about each subject area in isolation (multi-disciplinary pedagogical approach).
- Engages students in real-world learning, giving them a deeper understanding of concepts through relevant and authentic experiences. This prepares students to accept and meet challenges in the real world, mirroring what professionals do every day.
- Engages students deeply with the target content, helping to increase long-term retention. [1]

To use the project-based methodology for the integration of 3D printing technology as a tool for the development of innovation and creativity in furniture design, work can be done mainly by carrying out the project as a multi-stage exercise. The main steps for most of the exercises are:



Study and development of the idea	Design and adaptation to 3D printing	3D printing & Post-processing	Manufacturing processes	Analysis and functionality	Modify when necessary

Graphic 2: How to develop a project as a multi-stage exercise.

It should be noted that in the case of exercise 14, designed for people with disabilities, the methodology to be used will be Applied Behaviour Analysis (ABA). ABA is based on direct observations of behaviour as a primary measurement tool. The skills promoted must be objectively quantifiable and directly observable: the functional relationships between the individual and the environment are identified, objectively establishing causal relationships between environmental events, and observed behaviours. This process takes place through the systematic manipulation of the environment and the detection of behaviours exhibited under varying environmental conditions.

Learning Outcomes.

The **Learning Outcomes** that students will achieve through these exercises are as follows:

- ⇒ Identify printing problems**.**
- ⇒ Correct these errors by changing the printing parameters**.**
- ⇒ Anticipate possible errors before printing**.**
- ⇒ Exploit additional features of the printer**.**
- ⇒ To make a print with a loaded material (with particles of material (wood, rock, fibbers...) incorporated in PLA and ABS)**.**
- ⇒ To treat the points of hangs of the supports**.**
- ⇒ To define the parameters according to the expectations of the result (ex: high temperature = changes of colors and/or roughness of the material more pronounced)
- ⇒ A**bility to apply** different **finishes and understanding of** the different results **that we** can obtain depending on the **selected** techniques/products**.**
- ⇒ Anticipate and apply certain parameters upstream (during the creation of the G-code) to avoid certain phases of post-processing, and/or to give particular aspects to the different materials.
- ⇒ Self-sufficiency in finding out **the necessary** documentation**.**
- ⇒ Modeling of complex shapes and movables parts.
- ⇒ Details on positioning of a model to save on support**´s** material.
- ⇒ Self-sufficiency in dimensioning.
- ⇒ Surface modeling techniques.
- ⇒ Modeling of self-dependent and precise shapes.
- ⇒ Modelling of joint **fittings**.

⇒ Understand how to build joints and how to assemble parts of different materials.

⇒ Learn the laws of statics as **the student** will have to check whether the part is strong at the attachment and load points of the object.

⇒ To know the aspects related to the recyclability and circularity of materials and the protection of the environment.

⇒ Analyse and optimise design for 3D printing.

⇒ Know the influence of additive manufacturing on the design and prototyping of a product.

⇒ Know the use of 3D printing in the furniture market.

⇒ Acquire knowledge about the competitiveness of A**dditive** M**anufacturing** in the production sector.

⇒ Work with hybrid technology (wooden parts assembled with 3D printing parts).

⇒ Understanding material selection, printing orientation to achieve full strength of connectors.

⇒ Understand loading on seating chair and how to design connectors to withstand these forces -exercise could be extended to testing phase: chair could be tested according to standard EN 1729-2 Furniture.

⇒ Understand possibilities of tailoring the product to each user.

Section 4 of this document defines the 14 exercises that have been identified for this task. Each exercise consists of 4 parts:

1. Information, indicating the name of the exercise, the subject or topic to which it belongs and the number of pieces of the model.

2. Description of the 3D model. The model is described at a theoretical and graphical level. This is the basis for its subsequent design, which will be done in the second phase of this task and the results will be seen in the next deliverable "D3.5 New exercises using 3D printing (Including 3D models).

3. Teaching specification. This part gives answers to three questions that define how to integrate the exercise in the classroom/curriculum. How to use the model in the classroom, methodology to follow in class and the benefits of working with the exercise.

4. Technical specifications, where information about the printing technology, resistance, finishing, assembly, support material and others is collected.

3

Conclusions and links for the next deliverable

3. Conclusions and links for the next deliverable

This is the first deliverable **D3.4."Definition of new exercises using 3D printing"** of the task **T3.4."3D Printing Set of Exercises"**, which as mentioned in previous sections is the first step of the task. In this task, the exercises for the use and integration of 3D printing in studies related to furniture and wood have been defined. This first phase is the basis of the next deliverable **D3.5 "New exercises using 3D printing (including 3D models)"**, in which the final designs of the 14 exercises and the images of the printed models will be collected. These exercises will be integrated in the ALLVIEW e-Learning platform to be downloaded and used.

At this point, the next steps to complete this task are as follows:

⇒ 3D modelling of the defined exercises.

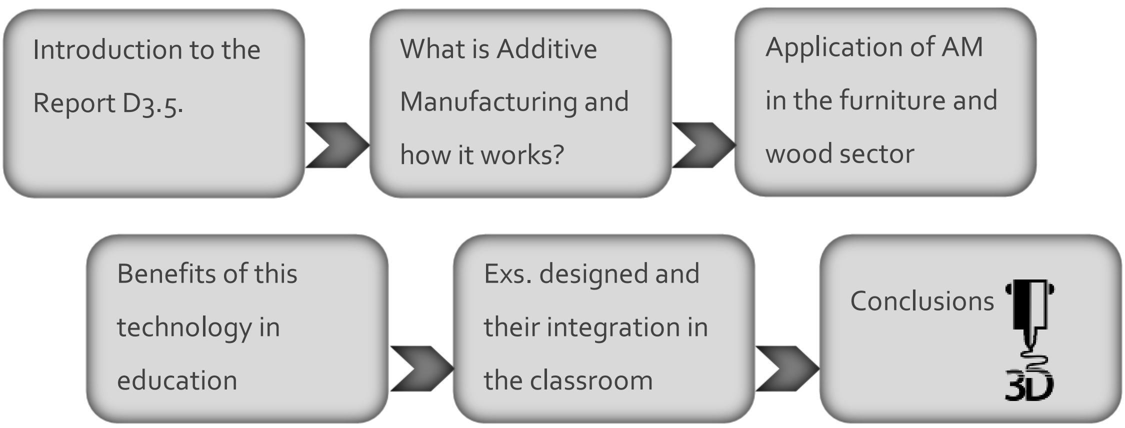
⇒ 3D printing of all the exercises for their correction or adaptation if necessary.

⇒ Update the definition of the 14 exercises and include the images of the renderings and printed models.

⇒ Integrate the .stl files and final descriptions of the exercises in the e-Learning platform developed for WP2 "Blended learning library for the Wood and Furniture sector".

⇒ Test the exercises developed under the study technologies of this work package (VR/MR/360Videos/3D Printing), together with the training contents developed under the WP2 framework in the WP5 "Dual Learning Cooperation" pilot experiences.

⇒ To write the report of deliverable D3.5 "New exercises using 3D printing (including 3D models)", which will include the following points:



Graphic 3: Structure of the next report D3.5.

Additive manufacturing processes allow for great design freedom, customization, earlier and easier assembly, and allow low volume production at low cost. These circumstances have a positive effect on the manufacturing of furniture.

Already starting in the design process, applications of 3D printing technologies have a positive effect on all further stages of product development and market launch. Just a few decades ago, the early design phase only comprised 2D drawings, which were the basis for the mostly hand-made prototypes. Today, companies also use modelling software and 3D printers at an early stage.

The prototyping process can be carried out much faster and more accurately using additive manufacturing technologies. In addition, 3D-printed prototypes with the same properties as the finished product can be produced and therefore also tested and evaluated. These new technologies greatly facilitate the development of complex and interlocking geometries.

This offers very good opportunities to introduce innovative designs to the furniture market that previously seemed impossible. By making complex design tasks more feasible, considerable amount of time can be saved, and new designs can be introduced to the market faster.

With the following report, we intend to make a progressive immersion in additive manufacturing technology, where the reader will acquire the necessary knowledge about what is and how this technology works, the main applications within the furniture and wood sector, the benefits of its use in education, together with the examples developed in this work package. We believe that this material will bring added value to those schools and teachers which want to get started in this field.

When you have a versatile technology and you put it in the hands of extremely motivated users, you have a perfect recipe for innovation. [2]

4

3D Printing set of exercises.
Defined Exercises.

4. 3D Printing et of exercises. Defined Exercises.

1. Exercise "Setting up a 3D printer for printing dedicated to the furniture sector"

INFORMATION

Exercise Name	"Setting up a 3D printer for printing dedicated to the furniture sector"
Specific Subject	Product Design, Sustainability, 3D printing
Number of pieces of which the model is composed	7 pieces

3D MODEL DESCRIPTION

Written description.

The goal is to design parts separately. It will allow the student to learn how to use and test the knowledge on each of the parameters of the 3D printer deposit of wire (FDM).
Depending on the parameters, we will have:

- Bridge/bridging tests
- Tests of angles and tips/hollows
- Precision tests (scale/diameter)
- Rope/rod tests
- Tolerance tests (wall/interwall)
- Cantilever angle tests
- Curve and rounding tests

The idea is to design different test modules allowing for each of them to test and validate the printer settings (depending on the material used).
There are different "test board" dedicated to 3D printing.

The idea is to make them independent of each other, in order to work on a precise setting and parameterization of the machine.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

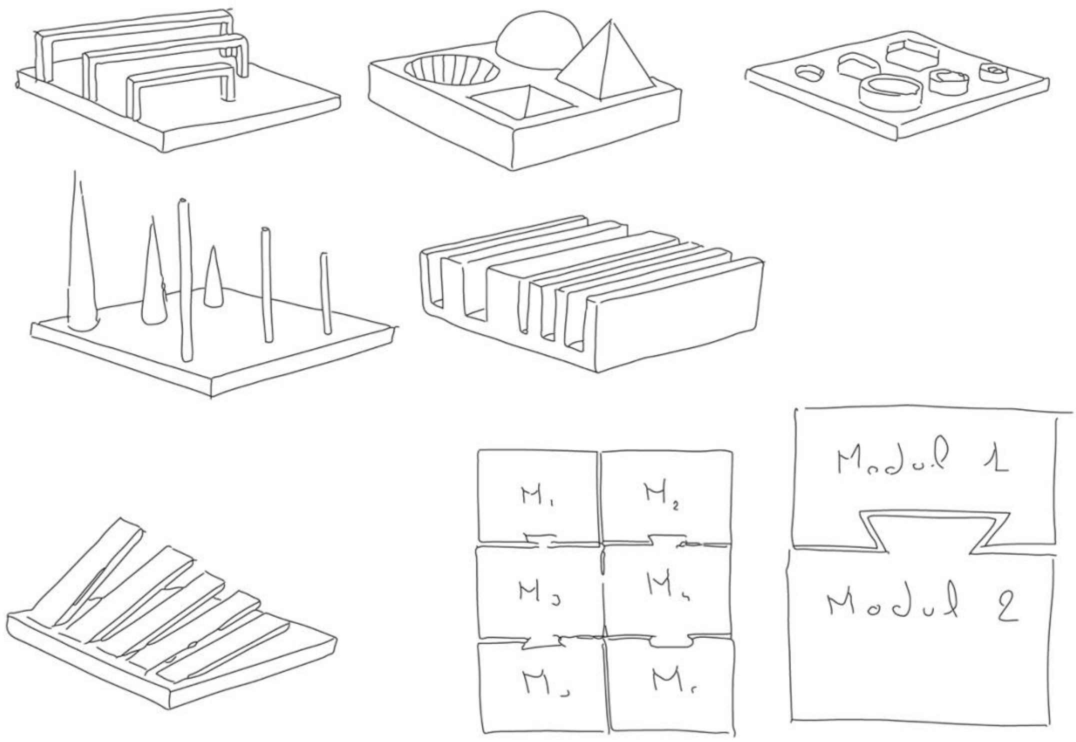


Figure 1: Model kits for testing.

Additional materials for a better description.

Example of a test board:

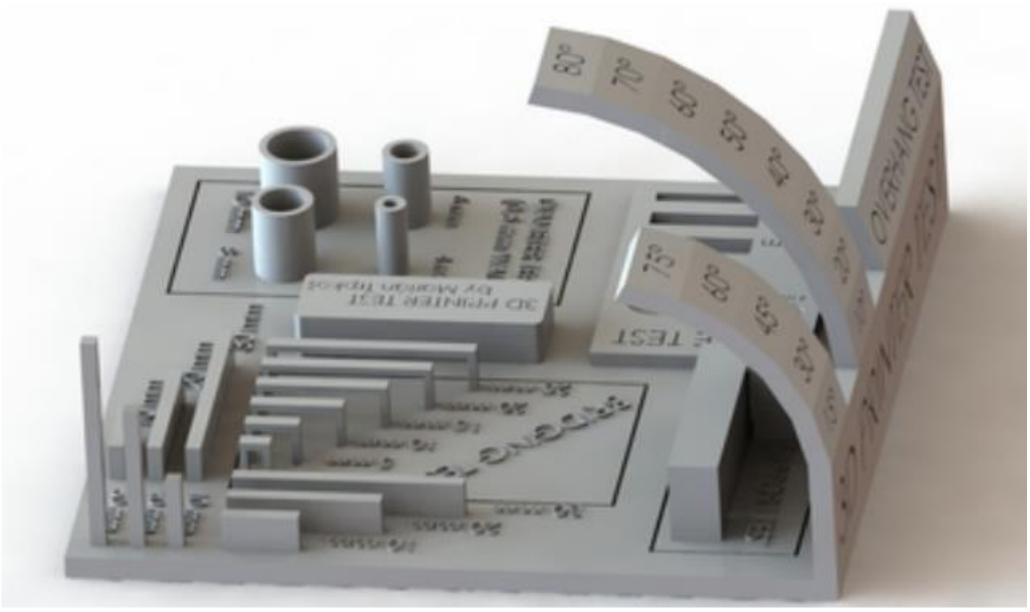


Figure 2: Example [3].

These modules can be printed according to the choice of settings we wish to validate/test.

The design of these parts will be done in such a way as to have each of the above-mentioned parameters associated with a part and a printout (this saves time during validation, if we intervene only on one aspect), so it will not be necessary to print a board including all the tests.

TEACHING SPECIFICATION

How can this model be used in the classroom?

This exercise is designed to make the student work on a limited number of settings depending on the part he will have to print.
The student's objective is to print one of the modules without encountering any printing problems (dripping, oozing, lack of material ...), it must leave the printer without any error.
Thanks to this exercise, the student will be able to determine the source of the problem during his future printing. Moreover, he will also be able to correct the parameters in order to ensure the good realization of his part by the machine.

What methodology can be used for its integration into the classroom/curriculum?

To ensure integration within a class/curriculum, the principle would be to provide to different students (or groups of students) a module on which work with.

This exercise can be worked on in class as a multi-step exercise:

- Prepare and run a printout of the module, having in mind when designing the G-code, that this part must come out identical to the 3D model.
- Identify the possible problems that we encounter/could encounter with this type of printing.
- List the parameters to influence to anticipate/correct the problems that could be linked to these different prints.
- Re-print the part with the appropriate corrections for a good printing execution.

Module-based learning is meaningful for students because they acquire the necessary skills to anticipate and correct printing errors that they might find in all their 3D printing projects.

What benefits can be obtained with its use?

The purpose of using this exercise is to provide to each student, through the realization of a successful print, with the necessary knowledge to understand the problems commonly encountered in the field of 3D printing with molten wire.

By pushing the exercise further, the students could also experiment by changing the parameters to see how the prints react according to the modifications.

In addition, these exercises determine the printing results, and by interacting with the associated parameters, they can discover and exploit aspects, usually avoided, to diversify the printing possibilities.

In terms of learning outcomes, the learner will be able to:

- Identify printing problems
- Correct these errors by changing the printing parameters
- Anticipate possible errors before printing
- Exploit additional features of the printer

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	Fused Deposition Modeling (FDM)
Material	PLA/ABS/PETG
Suitable dimensions for its use in the classroom (mm)	They will depend on the final design. They can be printed on a 200*200 tray without any problem.
Should the piece be resistant or be subjected to stress?	No
Number of pieces of which the exercise is composed:	6 pieces
Ensemble type if necessary (slot, clip, screwed ...)	
Accuracy and definition required. (Quality) Low, mid or High.	Medium or high (maximum nozzle diameter 0.4mm)
Support material or post-processing.	For a good realization of the exercise, it is not necessary to use supports and it is not necessary to carry out post-processing either.

2. Exercise "Materials and finishing dedicated to 3D printing (FDM)"

INFORMATION

Exercise Name	"Materials and finishing dedicated to 3D printing (FDM)"
Specific Subject	Product Design, Sustainability, 3D printing
Number of pieces of which the model is composed	1 piece

3D MODEL DESCRIPTION

Written description.

This 3D model aims to represent the different types of surfaces, structures, and shapes that could be met on prints. It will be composed in different ways to be able to work on the post-processing of the materials after printing.

It incorporates several aspects that can vary greatly depending on the materials used:

- The details in relief or inlays.
- Connections between two surfaces that are not on the same plane.
- Fillets and chamfers.
- Vertical and horizontal cylinders.
- Hollow and curved surfaces.
- Protruding edges.
- A temperature printing scale.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

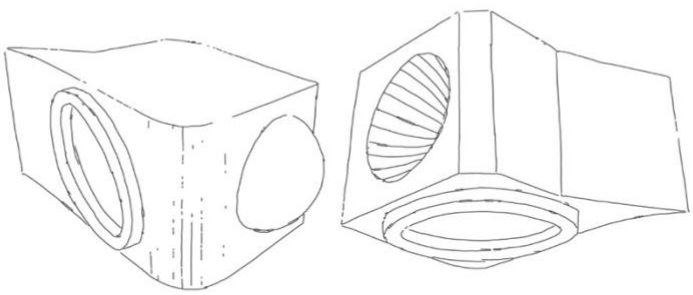


Figure 3: Model diagram of different surfaces.

Additional materials for a better description.

This "model" allows us to observe and work on the different types of surfaces that might be found on 3D prints.

Figure 4: Model example [4].

Here it is displayed an example of a model allowing to see the results of printing (it is useful as a basis to check the good settings of the printing parameters). The model of figure 4 doesn't offer the possibility to work on the post-processing of the material, as it incorporates very fine details which do not allow an easy "test post-processing" as opposite of the model of figure 3.

TEACHING SPECIFICATION

How can this model be used in the classroom?

This exercise will be presented in the form of a "practical work" during which the students will have to develop a good printing of the part in a first step (exercise similar to "Setting up a 3D printer for prints dedicated to the furniture sector").

In a second step, they will have to choose to apply one or several post-processing on the part after printing:

- Painting
- Varnishing
- Sanding
- Removal of clinging points/marks related to the supports
- Evidencing/sculpting
- Smoothing (with a hot iron)
- Texture work

What methodology can be used for its integration into the classroom/curriculum?

To ensure integration within a class/curriculum, the idea would be to pass the 3D model to the students to print and post-process in several steps:

- Preparation of the file in the form of G-Code (knowledge of the settings of a print, see exercise: "Setting up a 3D printer for prints dedicated to the furniture sector").
- Take into account the temperature tower in the configuration.
- Set up of supports adapted to the printing/exercise.
- Printing correctly to obtain a compliant part.
- Application of the various forms of post-processing (quoted in the higher paragraph, number of post-processing with the goodwill of the professor) on the printed part.
- This exercise can be repeated as many times as the user aims to work with a different material.

This exercise will allow the students to apprehend, according to the geometry of the part, the various problems which we can meet in post-processing according to the printed materials

Moreover, it also allows to perceive on which aspects to intervene upstream during the preparation of the G-code, in order to avoid certain steps of post-processing (detail depending on the materials used).

What benefits can be obtained with its use?

The purpose of this exercise is to make the student to experience the range of printing possibilities thanks to the printing of different materials and the various post-processing operations that can be applied. Moreover, the learner will experience the effects that will have on the final part. It will allow the students to experiment with surface treatments (sanding, milling, etc.) on the part in order to exploit the characteristics of the materials to the fullest extent possible in terms of their printing.

In terms of learning outcomes, the learner will be able to:

- To make a print with a loaded material (with particles of material (wood, rock, fibers ...) incorporated in PLA and ABS).
- To treat the points of hangs of the support.
- To define the parameters according to the expectations of the result (ex: high temperature = changes of colors and/or roughness of the material more pronounced).
- Application of different finishes, and the different results that we can obtain depending on the techniques/products they that use.
- Anticipate and apply certain parameters upstream (during the creation of the G-code) to avoid certain phases of post-processing, and/or to provide particular aspects to the different materials.

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	Fused Deposition Modeling (FDM)
Material	PLA ABS composits
Suitable dimensions for its use in the classroom (mm)	They will depend on the final design. They can be printed on a 200*200 tray without any problem.
Should the piece be resistant or be subjected to stress?	Yes/No (depending on the post-processing applied)

Number of pieces of which the exercise is composed:	1 piece
Ensemble type if necessary (slot, clip, screwed ...)	
Accuracy and definition required. (Quality) Low, mid or High.	Low, medium or high (minimum nozzle diameter 0.6mm because on smaller sizes, the particles present in the material may clog the nozzle).
Support material or post-processing.	Setting up supports is MANDATORY in order to approach the post-processing of the hanging places of the supports in a print.

3. Exercise "Eccentric connector"

INFORMATION

Exercise Name	Eccentric connector
Specific Subject	Design and print functional replacement of broken eccentric connector
Number of pieces of which the model is composed	1 piece

3D MODEL DESCRIPTION

Written description.

Eccentric connectors are probably the most popular joints in particleboard and medium-density fibreboard (MDF) flatpack furniture. Variety of these screws with plastic sockets are offered by many manufacturers for these kinds of joints. They are usually made of plastic or low strength metal, like ZAMAC, with a base metal of zinc and alloying elements of aluminium, magnesium, and copper. These connectors are usually not meant to be used multiple times and break easily when excessive force is applied. Due to the variety of products and manufacturers, it is usually problematic to find and replace a model used several years ago, especially when dimensional standards change. This exercise aims to design and print replacements for broken flange of the eccentric joint.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

There is a variety of available eccentric joints, they are also made of various materials, with similar function – join two panels together, usually at 90% angle.

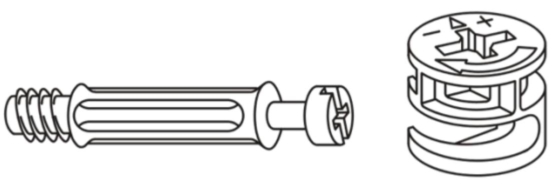


Figure 5. Typical eccentric joint.

The connector will be a simplified version of original ZAMAC connector, which happened to break. Geometry of the original connector is relatively complex. In order to save up on material, our version will be simplified, because it is going to be made of plastic (preferably ABS) and some strength will be needed. Original connector flange, while you still have it:

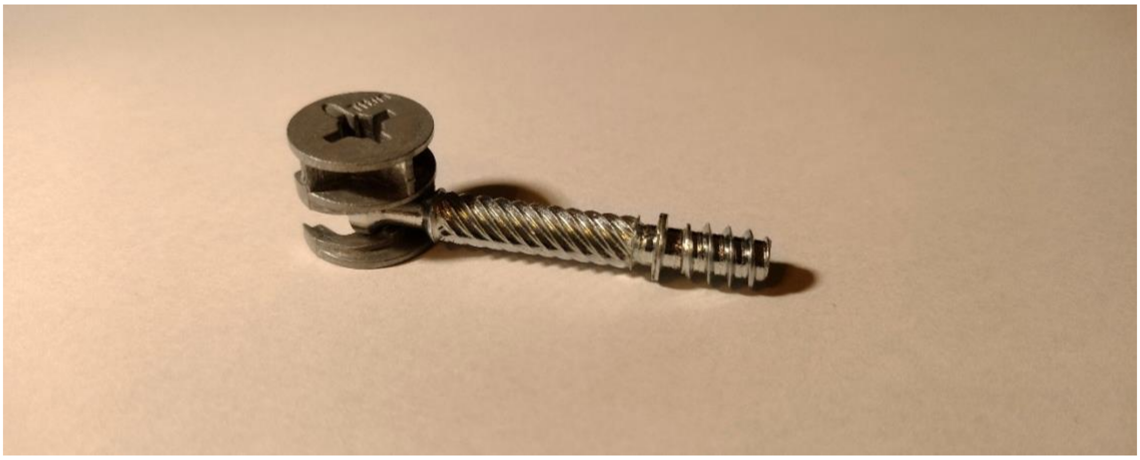


Figure 6. Sample eccentric connector.

Unfortunately, these flanges tend to break:

Figure 7. Connector flange with broken off (almost) piece.

Crucial for understanding how to model one, is to have the dimensions of the original one. In our case it is 13mm high with 15mm diameter. We start with a simple block:

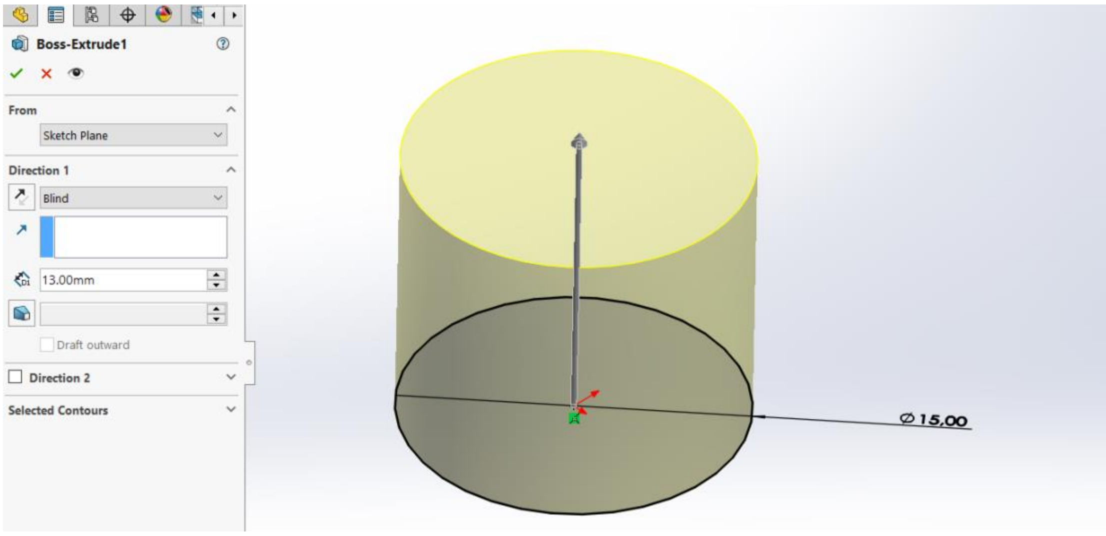


Figure 8. Flange block.

It is needed to create two sketches, one with measured opening, and the second with eccentric path:

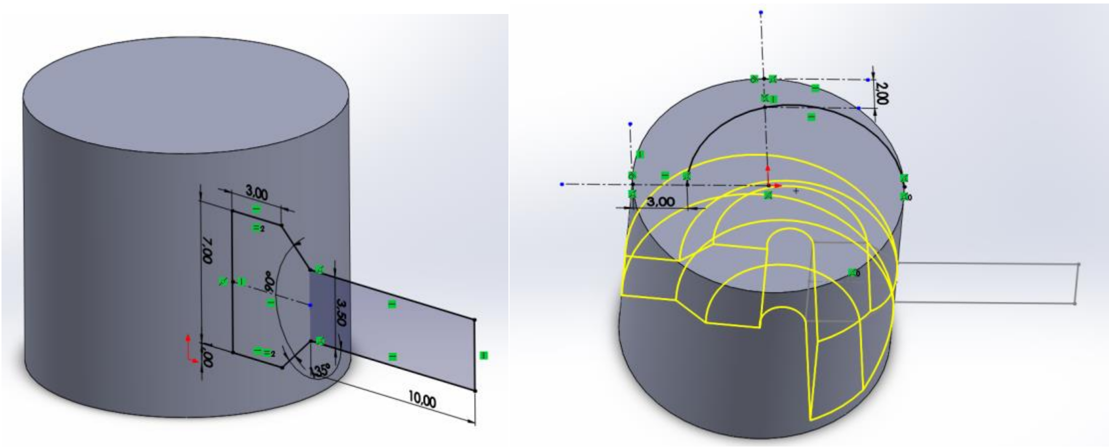


Figure 9. Opening and eccentric path sketches.

And combine into eccentric opening of a given profile:

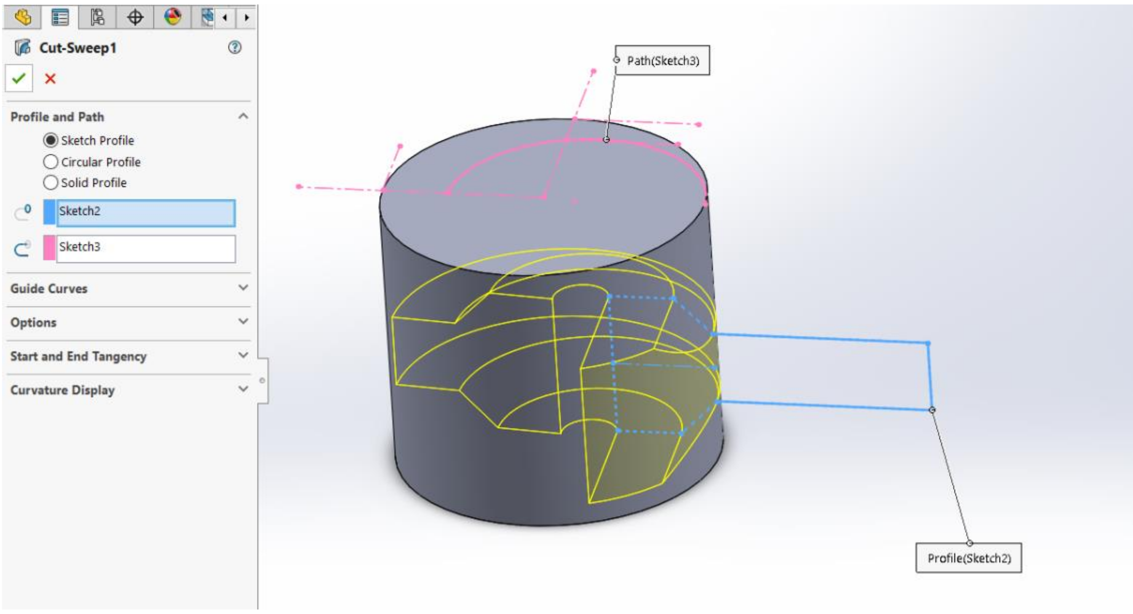


Figure 10. Opening cut.

Obviously, dimensions of both are dependent on the one flange that you have.

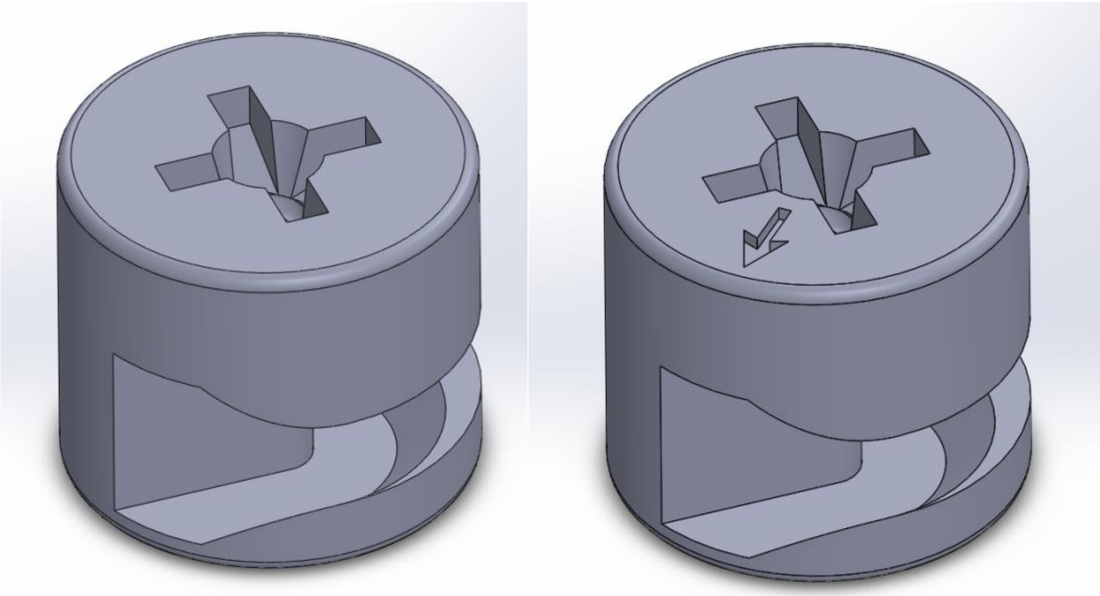


Figure 11. Connector model.

It is necessary to cut Philips or hex socket for the screwdriver that you have, as well as point direction in which flange is going to be positioned during the assembly.

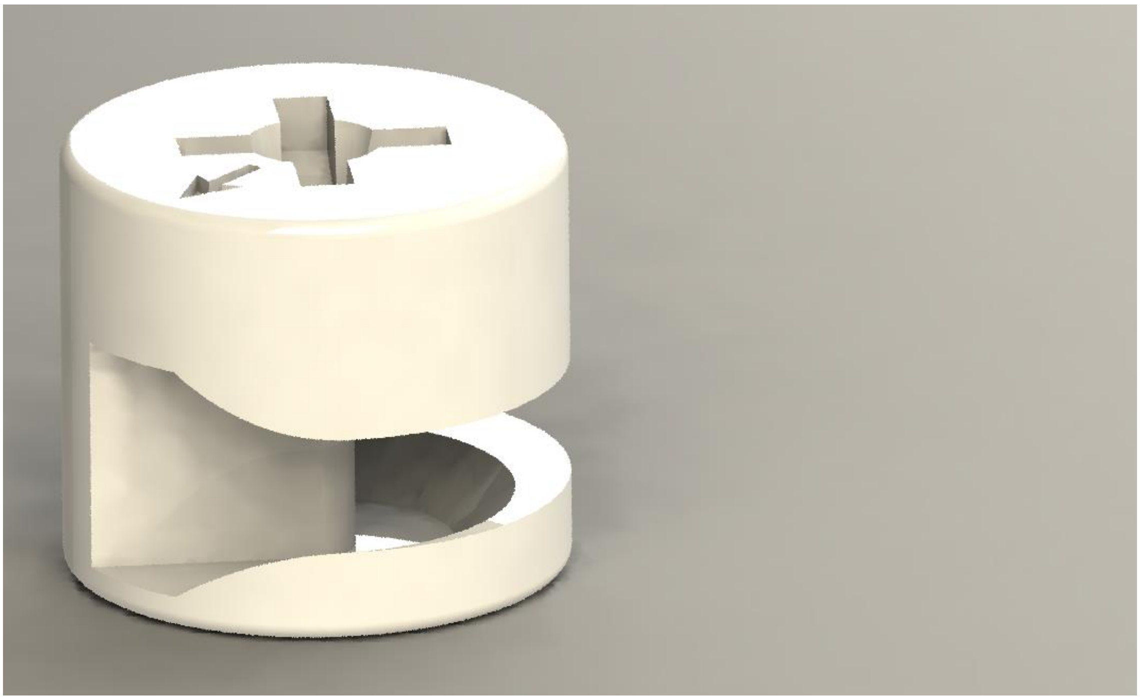


Figure 12. Finished connector.

TEACHING SPECIFICATION

How can this model be used in the classroom?

This exercise is designed to provide the student with the necessary knowledge on how to creatively model working mechanical part and scale it to required dimensions.

What methodology can be used for its integration into the classroom/curriculum?

The connector will be fully modeled / printed by each student, to a given standard or non-standard existing dimensions or real example of the flange, to be measured by student. Model after printing should be cleaned and checked against functionality. Will it pull the connector?

What benefits can be obtained with its use?

The students will learn about:

- Self-sufficiency in dimensioning.
- Modeling of precise shapes.
- Details on printing of a model, to provide sufficient loose fit.

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM, due to quality-price ratio of materials and machine.
Material	ABS recommended due to higher strength. PLA possible, not recommended due to lower strength, can be used in the exercise however
Suitable dimensions for its use in the classroom (mm)	Here, it must be specified the necessary size of the object or model. You can just provide connector to duplicate, or indicate general dimensions, printing will be done 1:1
Should the piece be resistant or be subjected to stress?	Practical model – due to mechanical nature and necessary squeezing with assembly it needs to be printed with 100% infill
Number of pieces of which the exercise is composed:	Single piece matching to given connector
Ensemble type if necessary (slot, clip, screwed ...)	Screw-on assembly, some areas may need to be manually cleaned and sanded to fit
Accuracy and definition required. (Quality) Low, mid or High.	Medium to high quality, visual appearance and precise dimensions of the functional model is a key
Support material or post-processing.	Support material can be the same as printing material, removal and cleaning up model necessary

4. Exercise "Cable route"

INFORMATION

Exercise Name	Cable route
Specific Subject	Design of cable route prototype for furniture with moving and matching parts
Number of pieces of which the model is composed	3+ piece – dependent on length required

3D MODEL DESCRIPTION

Written description.

Cable routes are the structures used to protect the cable from mechanical stress and harsh situation such as abrasion which might degrade the insulation, while improving visual appeal and tidying up overall looks of the workplace. A simple desk cable route will be dedsigned for pass-thru of some wires, usually for computer or phone use, with limited bending radius.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

There is a variety of available cable routes, made of various materials, with similar function – prevent damage of the cables against regular usage and external dangers like vacuum cleaner. Other not so obvious problem that can be addressed, is the lack of cable bend-radius control, especially important in fiberoptics, and furniture-reconfiguration limitations.

Figure 13. Traditional cable routing.

Figure 14. Flexible wiring duct [5].

Figure 15. Flexible cable snake [6].

Our cable snake will be based on two grommet cases, aimed at pushing into existing predrilled hole in the desk, with modules required to join the grommets making elastic route. In our case, bending will be limited to 15 degrees, so they can be applied to fiberoptics too. This is a sample design only and you may decide on details, diameter, and length on your own.

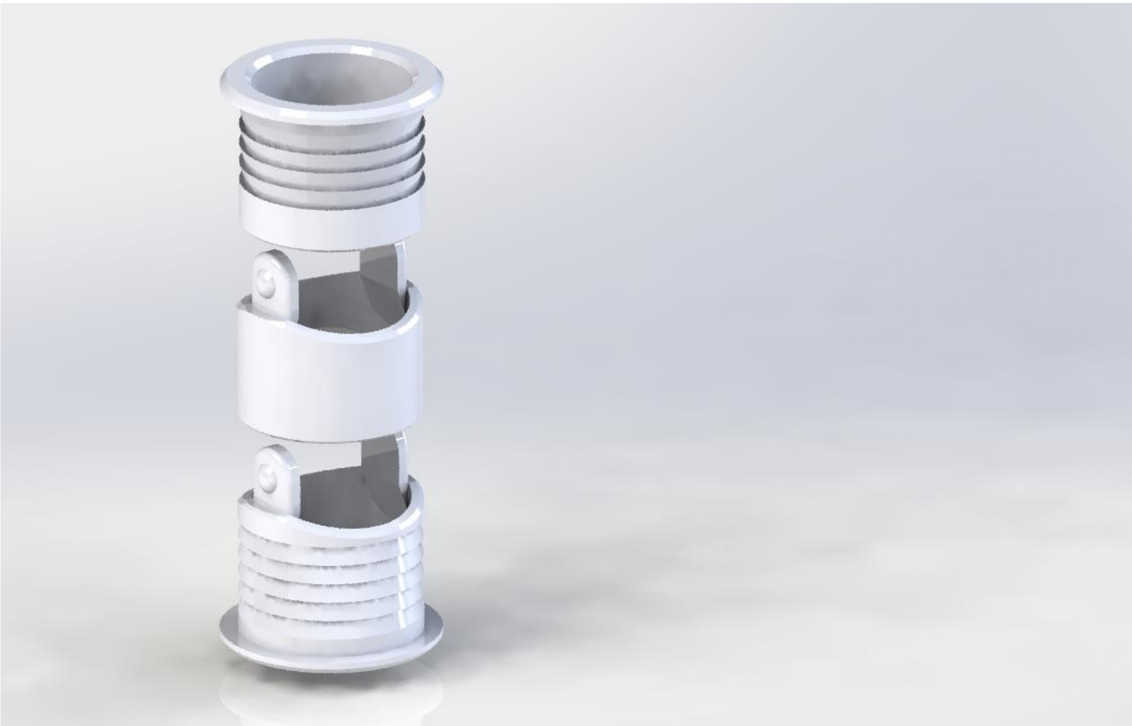


Figure 16. Sample exploded assembly of cable snake.

Figure 17. Connector should be printed out in required number as this part providing length of the unit.

Assembly of the product should be made by simple pushing parts into place, add as many connectors as you wish

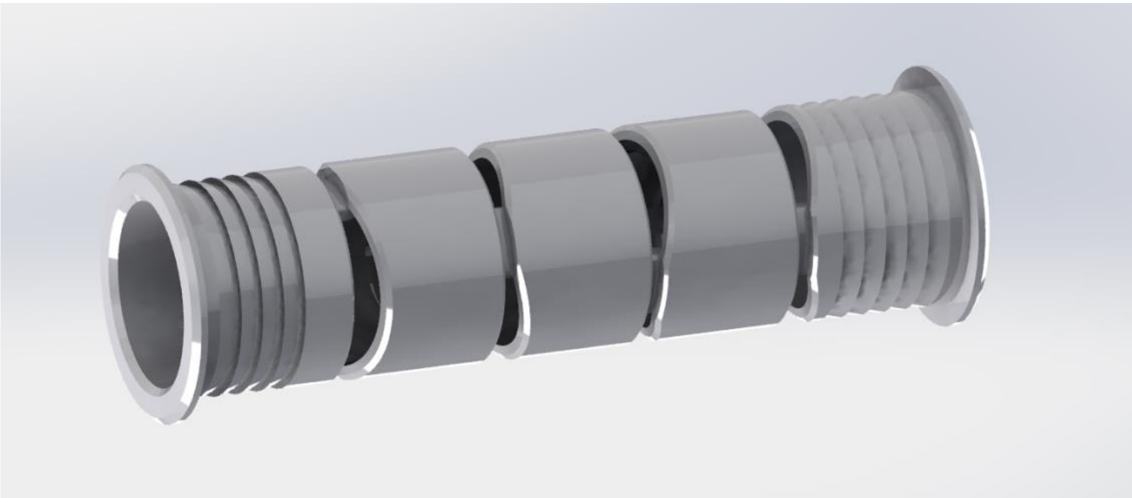


Figure 18. Assembled cable snake.

It is easy to see, that each connector can be rotated independently, in any direction set by rotating part around its own axis.

To understand how to model one, it is crucial to have the dimensions of the desk opening, and thickness of the board – in this case opening of 30mm and board thickness of 19mm were assumed – this can obviously be adjusted as needed.

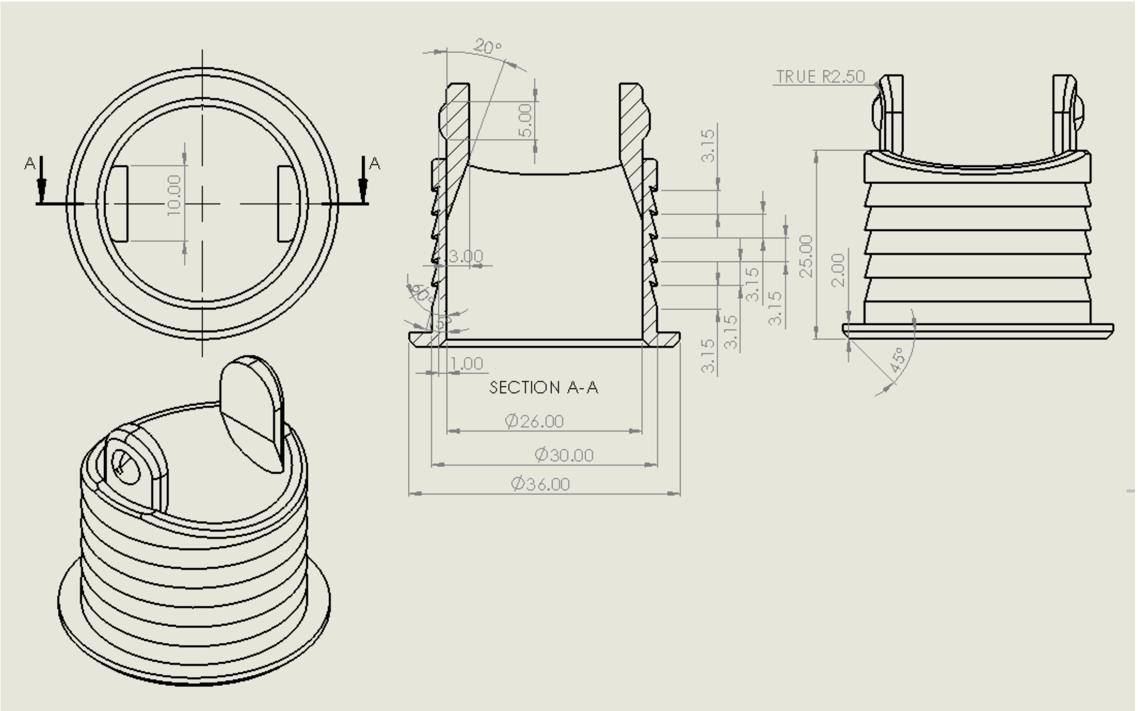


Figure 19. Bottom grommet case dimensions.

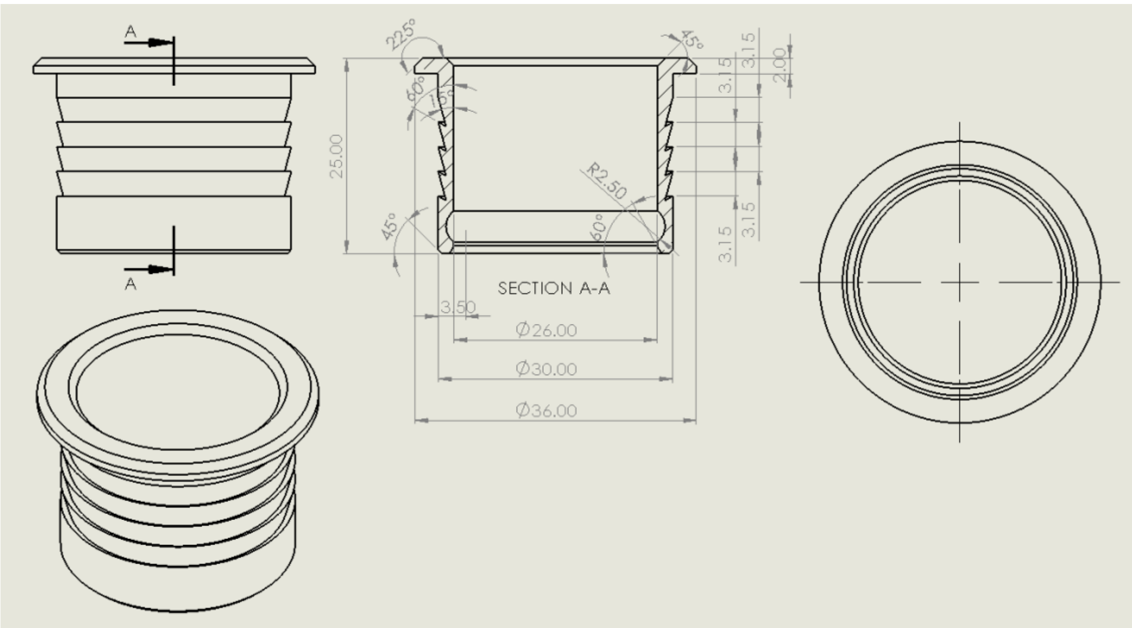


Figure 20. Top grommet case dimensions.

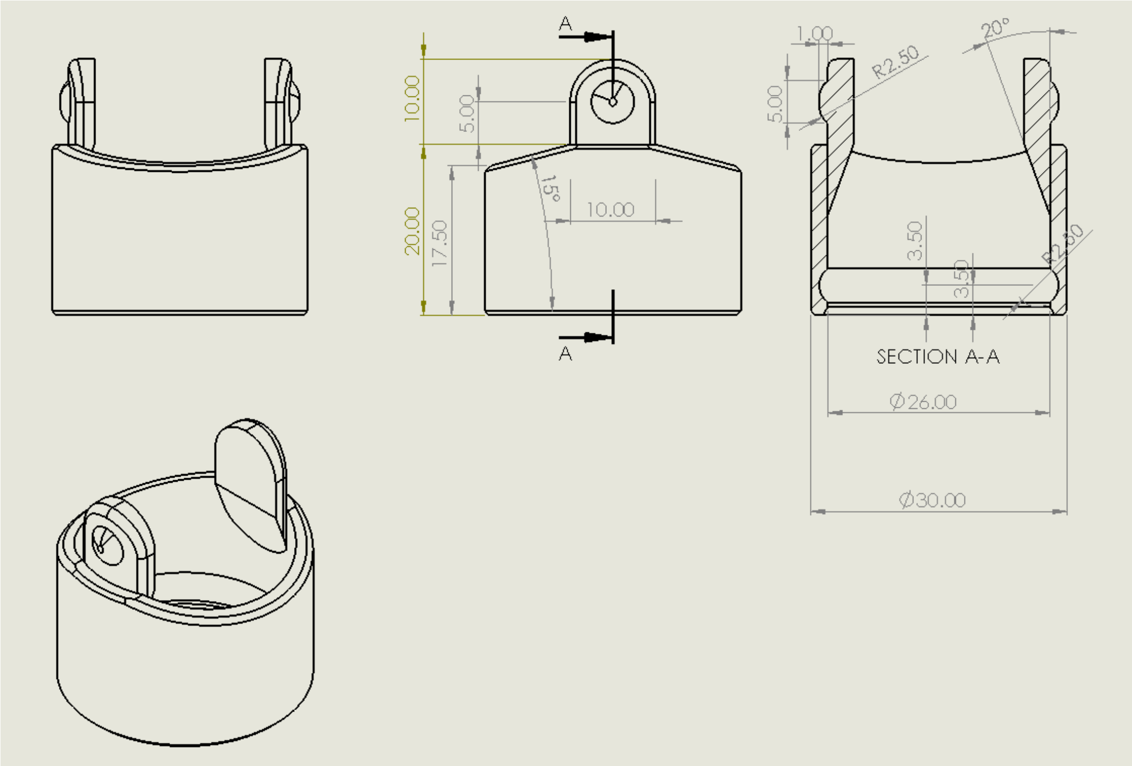


Figure 21. Connector dimensions.

Despite of the set dimensions of original model, it is relatively easy to scale model down or up to custom bore, length, and panel thickness.

TEACHING SPECIFICATION

How can this model be used in the classroom?

This exercise is designed to provide the student with the necessary knowledge on how to creatively model complex part and scale it to required dimensions.

What methodology can be used for its integration into the classroom/curriculum?

The cable snake will be fully modeled / printed by each student, to a given standard or non-standard dimensions, basing on the suggestions. The student will also have to determine best printing orientation of a model – to minimize waste material

What benefits can be obtained with its use?

The students will learn about:

- Self-sufficiency in finding out the necessary documentation.

- Modeling of complex shapes.
- Modeling of movable parts.
- Details on positioning of a model, to save on support material.

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM, due to quality-price ratio of materials and machine.
Material	PLA recommended due to hygienic measures. ABS possible, not recommended due to thermal shrinking and deformation of a thin structure
Suitable dimensions for its use in the classroom (mm)	Here, it must be specified the necessary size of the object or model. You can indicate very general dimensions, like bore and panel thickness, so printing will be done 1:1
Should the piece be resistant or be subjected to stress?	Practical model – due to thin walls and necessary squeezing with assembly it needs to be printed with 100% infill
Number of pieces of which the exercise is composed:	3+ matching pieces, depending on length
Ensemble type if necessary (slot, clip, screwed ...)	Push-on assembly, some areas may need to be manually sanded to fit
Accuracy and definition required. (Quality) Low, mid, or High.	Medium to high quality, visual appearance and precise dimensions of the functional model is a key
Support material or post-processing.	Support material can be the same as printing material, removal and cleaning up model necessary

5. Exercise "Cable grommet"

INFORMATION

Exercise Name	Cable grommet
Specific Subject	Design of cable grommet prototype for furniture with moving and matching parts
Number of pieces of which the model is composed	3 pieces

3D MODEL DESCRIPTION

Written description.

Cable grommets are a sort of cable accessories designed for use with electrical cables. They are usually made of, plastic, rubber or metal and are commonly used when wires need to pass through a panel. Cable grommets are produced as other types of grommets (wire, panel grommets, desk grommets, cable entry grommets and more). In our case, we will design simple desk grommet, for pass-thru of some wires, usually for computer or phone use.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

There is a variety of available desk grommets, made of various materials, with similar function to prevent damage of the cables against sharp edge of cable opening in the laminated chipboard, usual material used for work desks.

Figure 22. Cable grommets.

Our cable grommet will be based on grommet case, aimed at pushing into existing predrilled hole in the desk, with removable top and cable inlet, with adjustable opening. This is a sample design only. You may decide on details on your own.

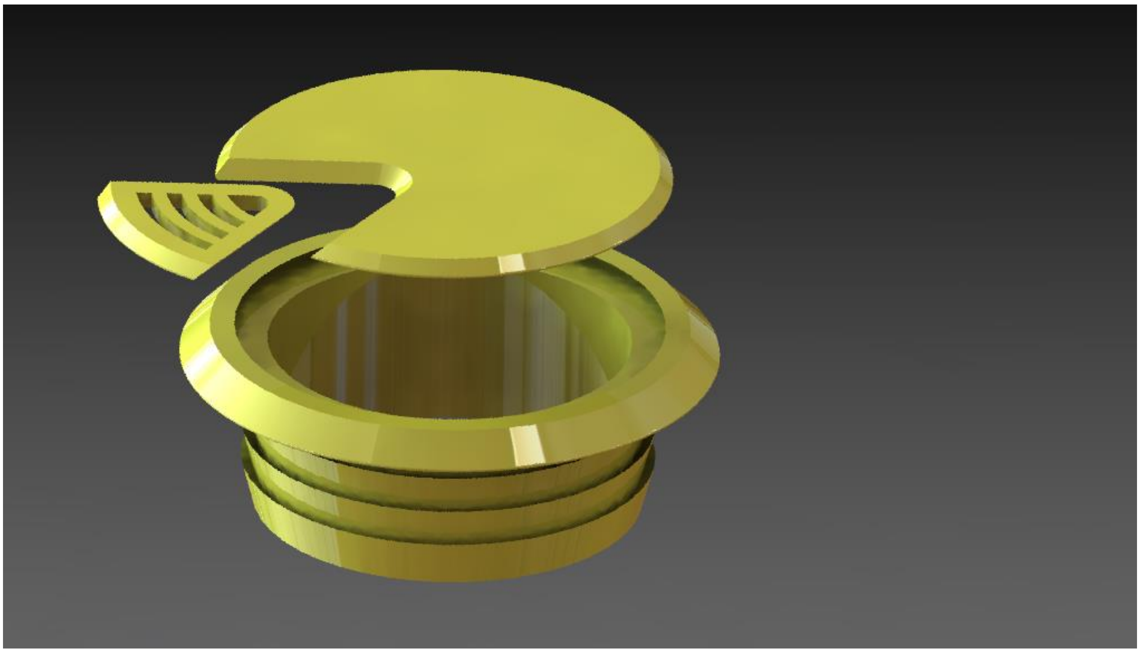


Figure 23. Sample exploded assembly of grommet case, removable top and adjustable cable plug.

Assembly of the product should be made just by simple pushing parts into place:

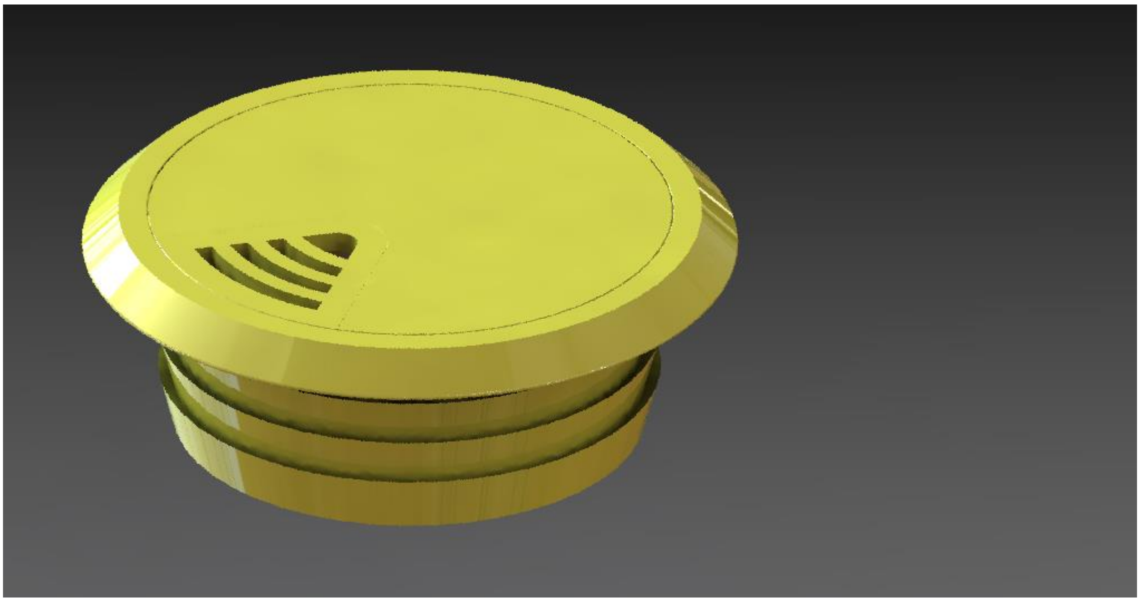


Figure 24. Assembled grommet.

It is crucial to have the dimensions of the desk opening, and thickness of the board to understand how to model one. In this case opening of 50mm and board thickness of 19mm were assumed – this can be adjusted as needed.

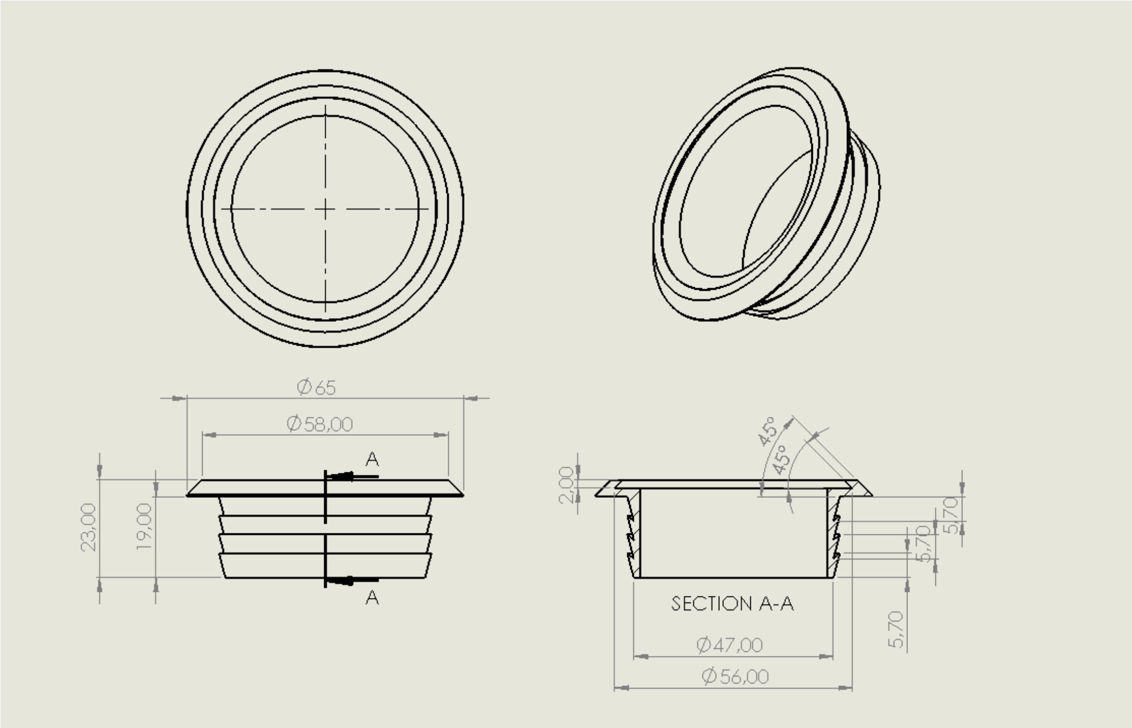


Figure 25. Grommet case dimensions.

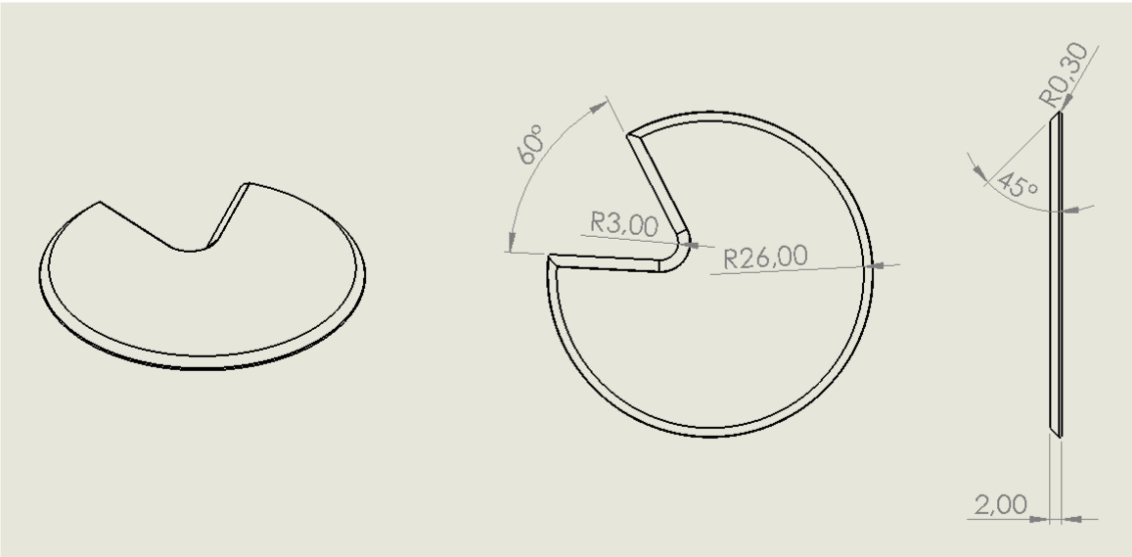


Figure 26. Top cover dimensions.

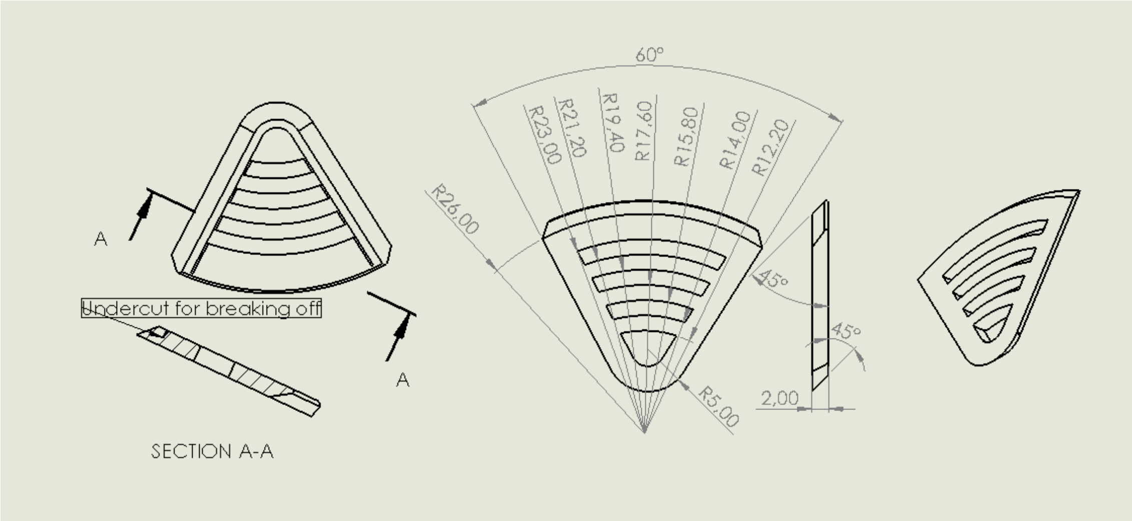


Figure 27. Plug dimensions.

Despite the fixed dimensions of the original model, it is relatively easy to scale the model down or up to fit the orifice and panel size.

TEACHING SPECIFICATION

How can this model be used in the classroom?

This exercise is designed to provide the student with the necessary knowledge on how to creatively model complex part and scale it to required dimensions.

What methodology can be used for its integration into the classroom/curriculum?

The grommet will be fully modeled / printed by each student, to a given standard or non-standard dimensions, basing on the suggestions. Student will also have to determine the best printing orientation of a model – to minimize the waste of material.

What benefits can be obtained with its use?

The students will learn about:

- Self-sufficiency in finding out the necessary documentation.
- Modeling of complex shapes.
- Modeling of movable parts.
- Details on positioning of a model, to save on support material.

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM, due to quality-price ratio of materials and machine.
Material	PLA recommended due to hygienic measures. ABS possible, not recommended due to thermal shrinking and deformation of a thin structure
Suitable dimensions for its use in the classroom (mm)	The necessary size of the object or model must be specified. Very general dimensions can be indicated, e.g.: bore and panel thickness, so printing will be done 1:1
Should the piece be resistant or be subjected to stress?	Practical model – due to thin walls and necessary squeezing with assembly it needs to be printed with 100% infill
Number of pieces of which the exercise is composed:	3 matching pieces
Ensemble type if necessary (slot, clip, screwed ...)	Push-on assembly, some areas may need to be manually sanded to fit
Accuracy and definition required. (Quality) Low, mid or High.	Medium to high quality, visual appearance and precise dimensions of the functional model is a key
Support material or post-processing.	Support material can be the same as printing material, removal and cleaning up model necessary

6. Exercise “Prototyping in 3D printing”

INFORMATION

Exercise Name	Prototyping in 3D printing
Specific Subject	Design of furniture which could be hard to prototype with other technology
Number of pieces of which the model is composed	Multiple pieces

3D MODEL DESCRIPTION

Written description.

The cornered coffee table is an example of contemporary furniture, designed by Dylan Gold (*https://www.dylangold.com/custom-furniture*)

It doesn´t differ too much from average coffee table, but one of the legs is replaced with an angled cubic form for holding newspapers and magazines.

Dylan Gold:

“Cornered”, as we call it, means to be simple. It values clean surface area yet holds a place for your favourite few books or magazines. It’s just your average coffee table with one leg constructed as a cross-section of a rotated cube that embodies the inherent function of all coffee tables. Nice and easy” (https://karmatrendz.wordpress.com/2010/01/11/cornered-table-by-dylan-gold/)

Cornered coffee table is relatively simple in construction, however, it is complex to prototype, due to the multiple angles of the designed parts - common machinery is not designed for these tasks, so 3D printing could be useful in this case, to allow its visualisation.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

Cornered coffee table is based on regular coffee table, with thick standard legs and cubic box made of four angularly cut parts:

Figure 28. Cornered coffee table [7].

Crucial to understanding how to model one, is to recognize cubic structure which is perfectly rectangular, but angled in two directions:

Figure 29. Cornered coffee table box front view [7].

Whole box is cut at an angle, so all the parts would be angle-cut in two directions.

Figure 30. Cornered coffee table box view [7].

Despite set dimensions of original model, it is relatively easy to scale model down or up to custom size, like for kids or population which doesn't fit standard dimensions.

Additional materials for a better description.

First start assembly with just worktable part, of 1000x1000x50 dimensions

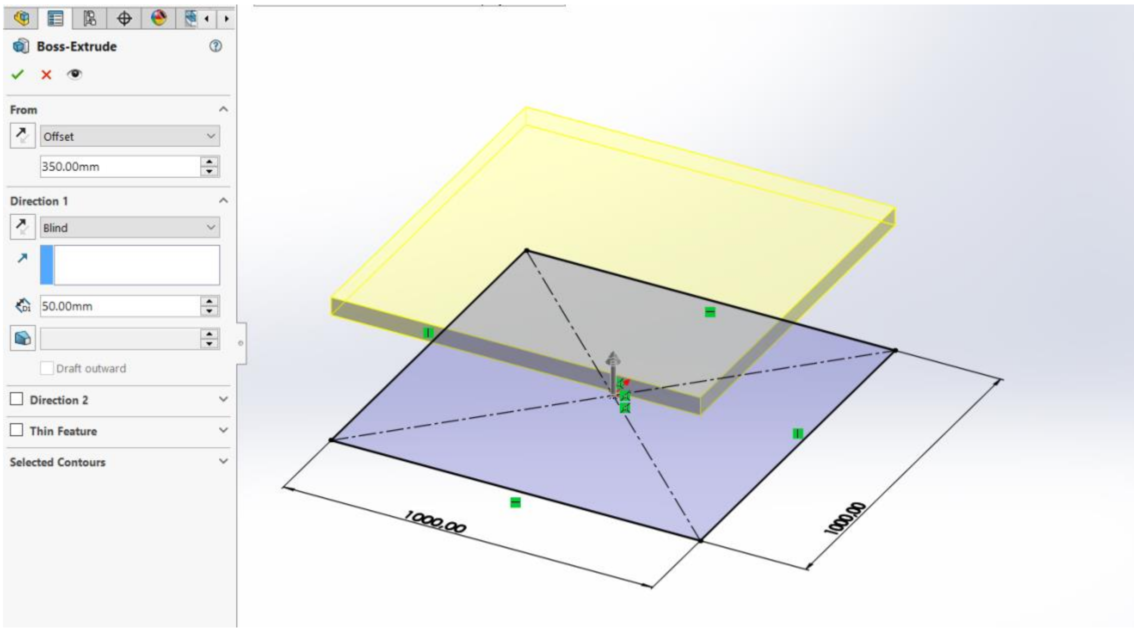


Figure 31. Worktable sketch and extruded part.

Then, lets sketch and taper-extrude a leg on the bottom of the table.

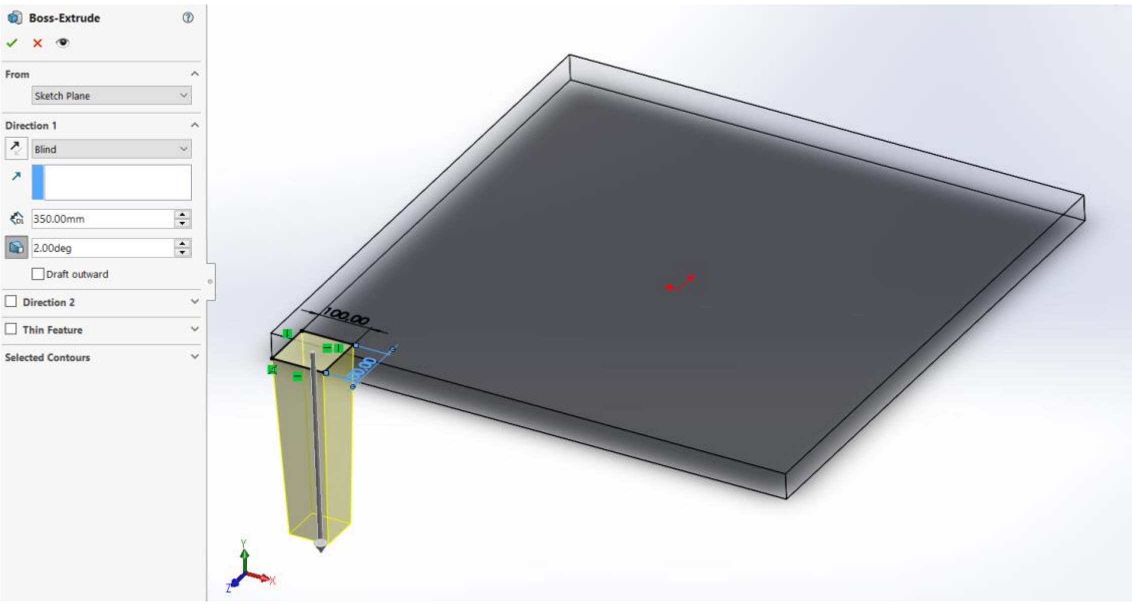


Figure 32. Tapered leg.

Possibly, at this stage, some joints could be needed:

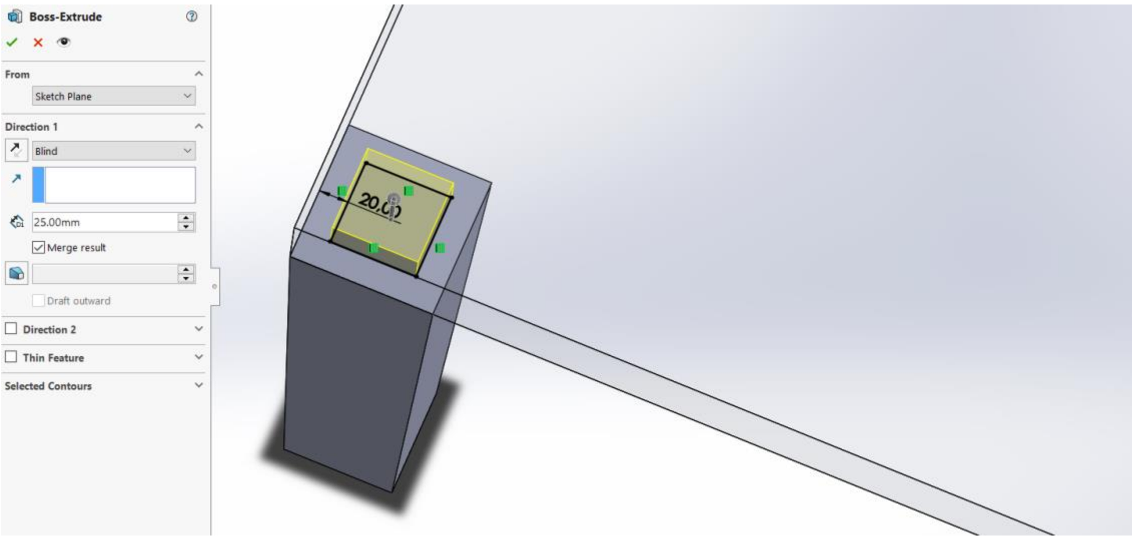


Figure 33. Leg joint.

After that – we can copy or mirror parts into table corners:

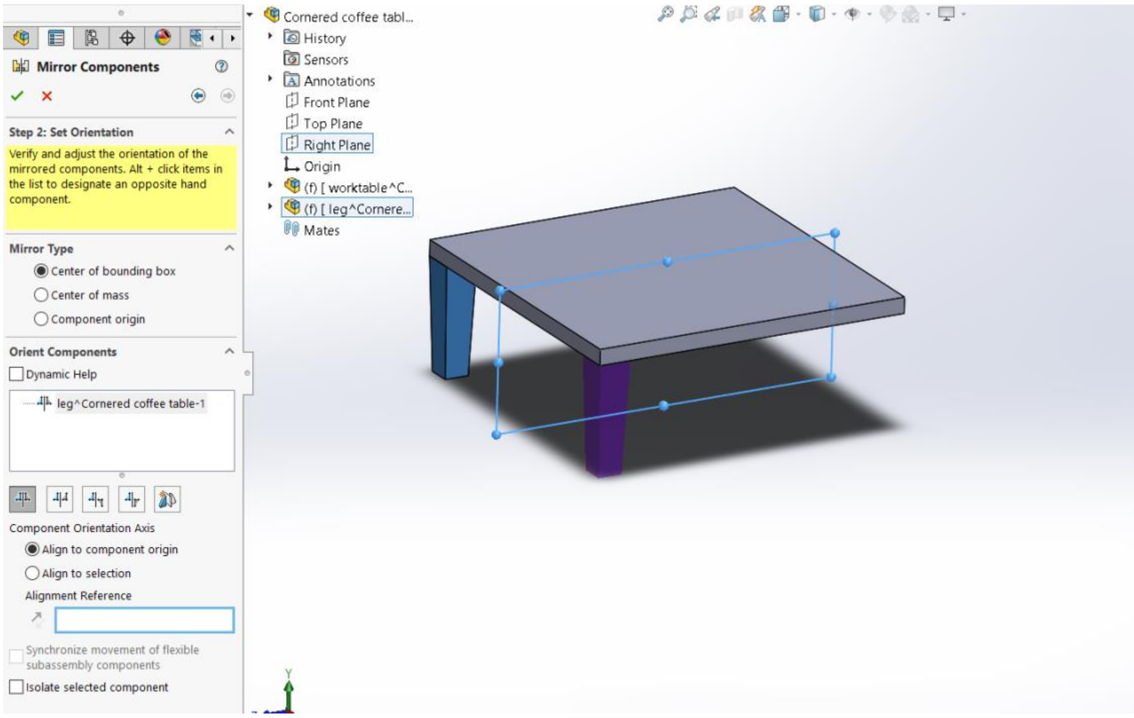


Figure 34. Mirror leg.

Obviously, we need to do it twice:

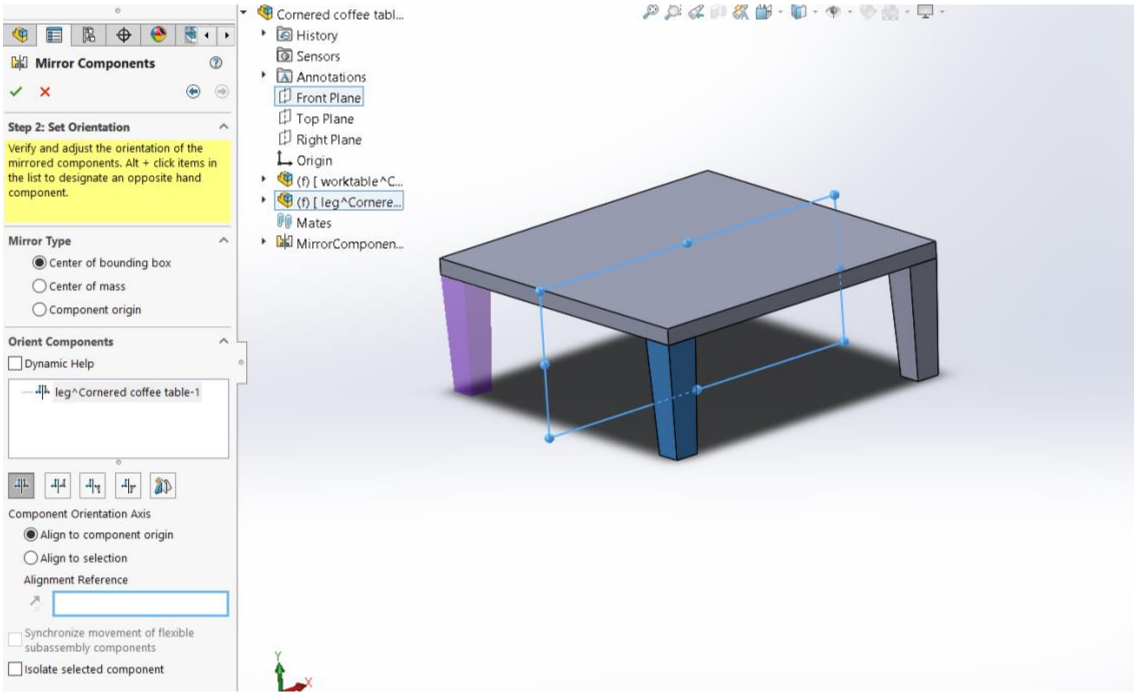


Figure 35. Second leg mirror.

Now let's sketch and cut opening – no dimensions are crucial, except parallel distance of 50 mm to the corner – we need to align side boards later:

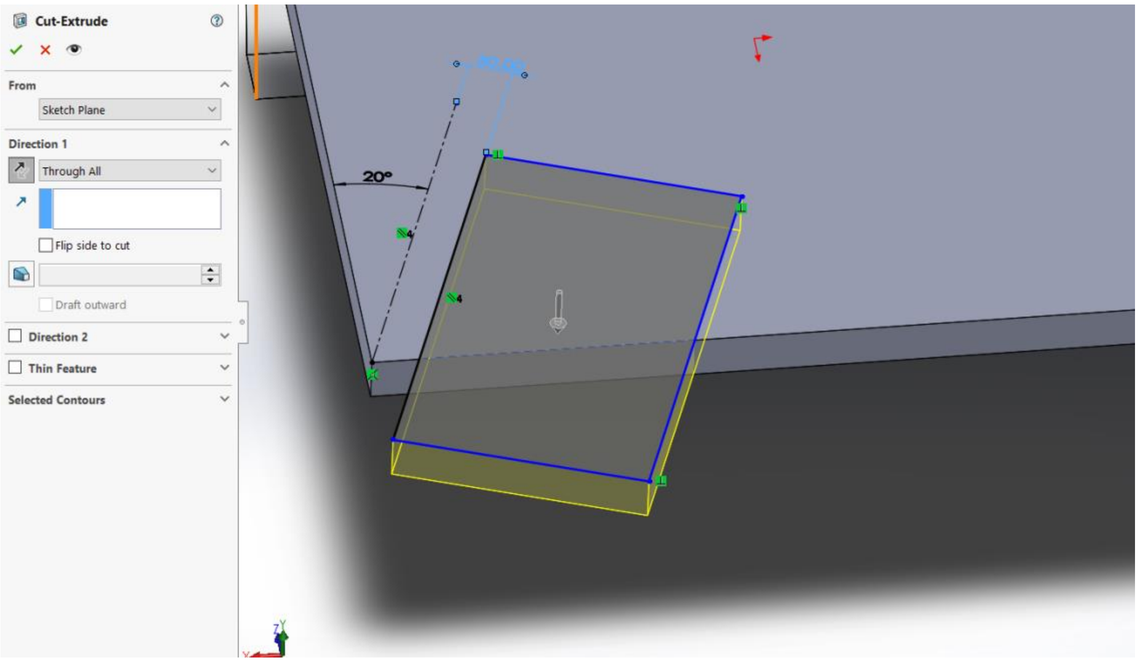


Figure 36. Cut of table opening.

And add some angle to the opening:

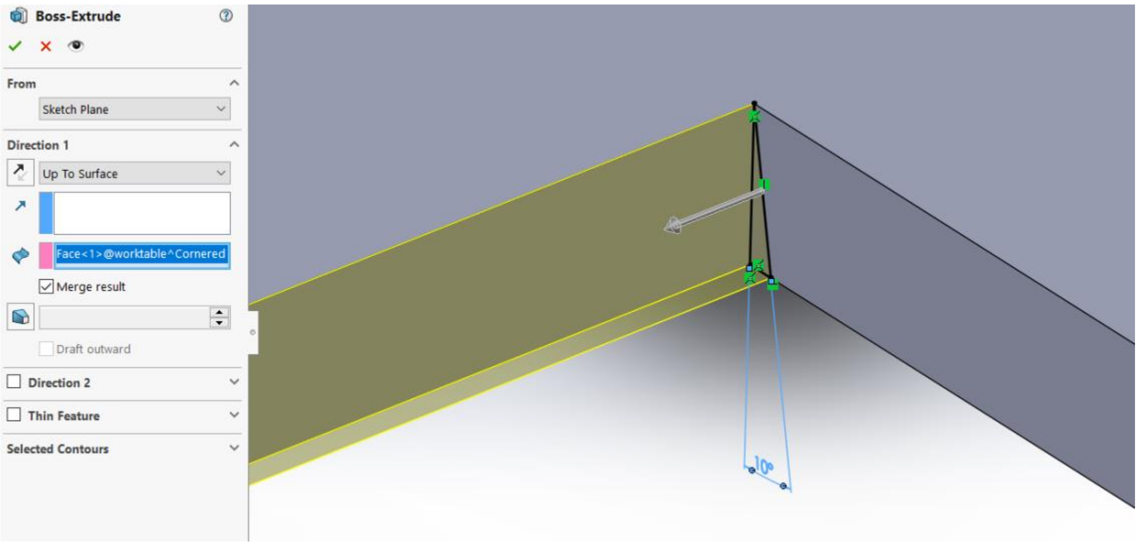


Figure 37. Table cut angle.

Now we can model box parts:

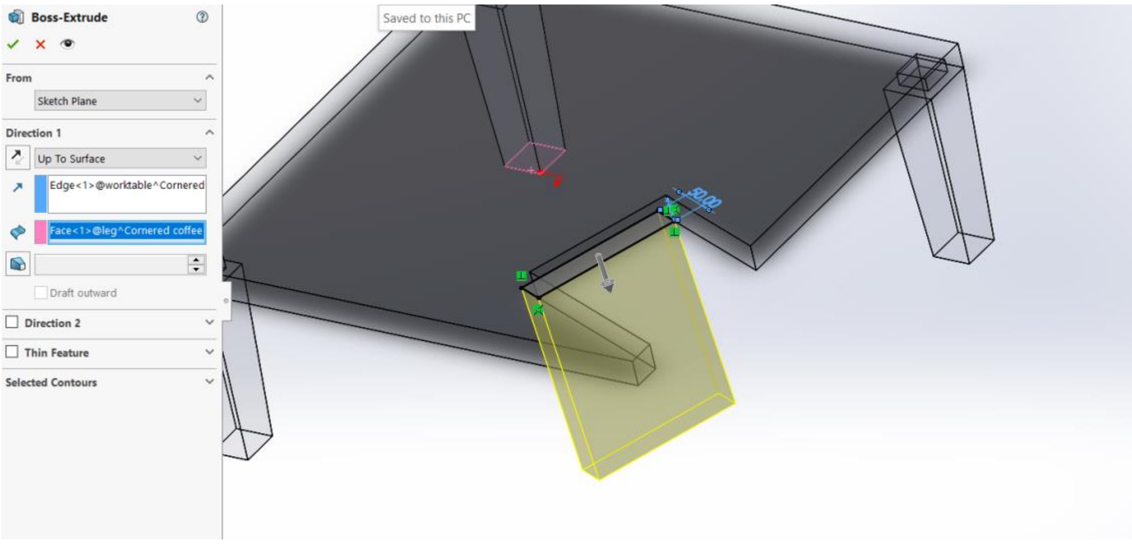


Figure 38. Box rear panel.

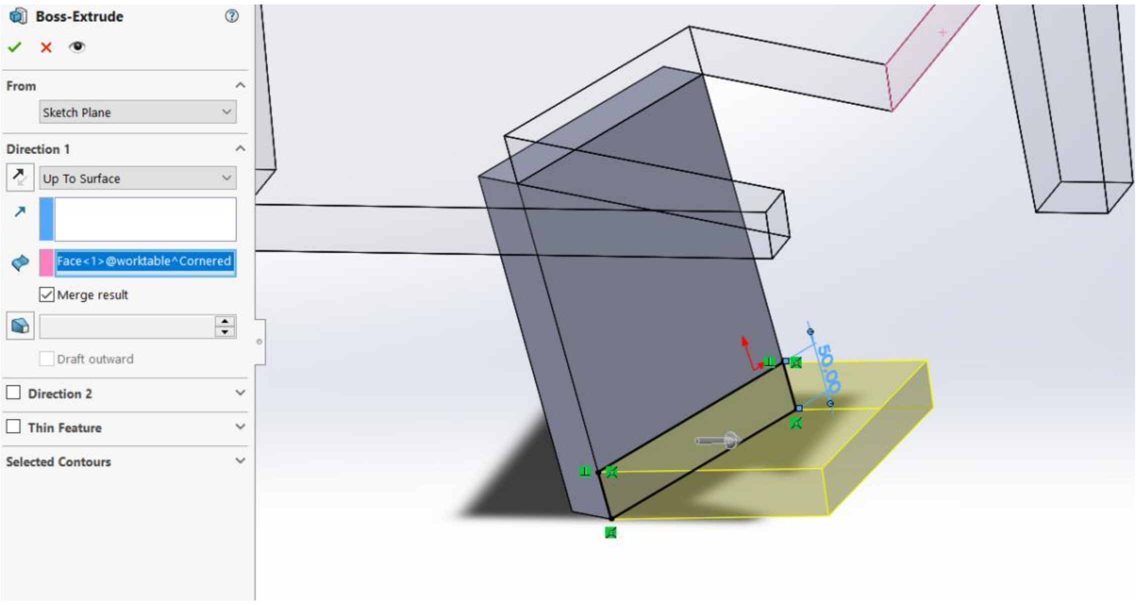


Figure 39. Box bottom panel.

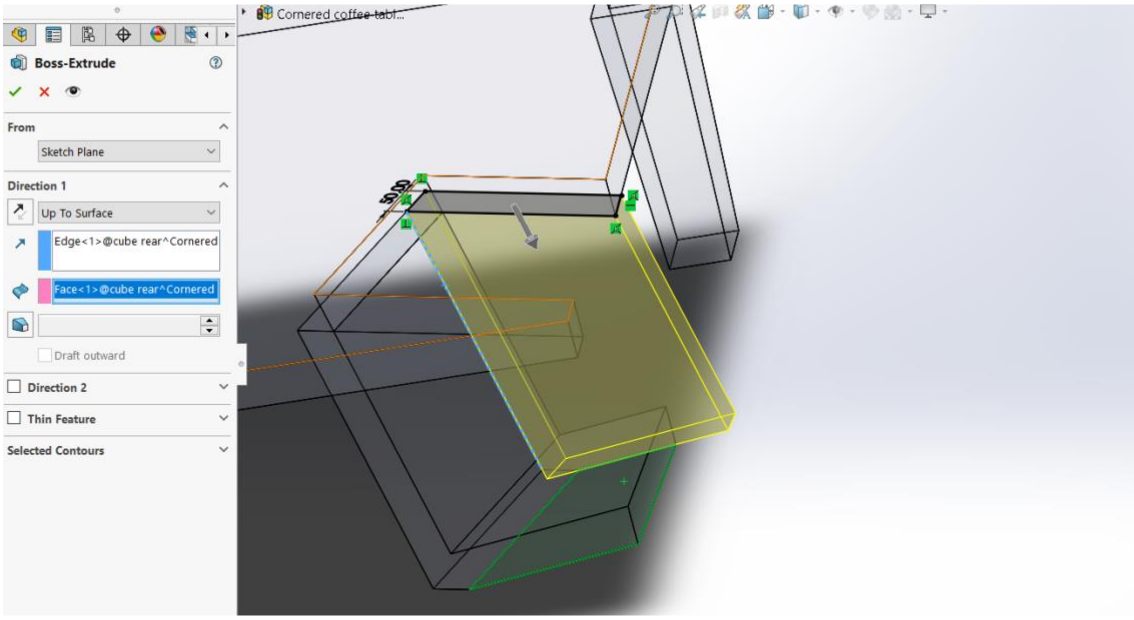


Figure 40. Right and left side modelled the same way.

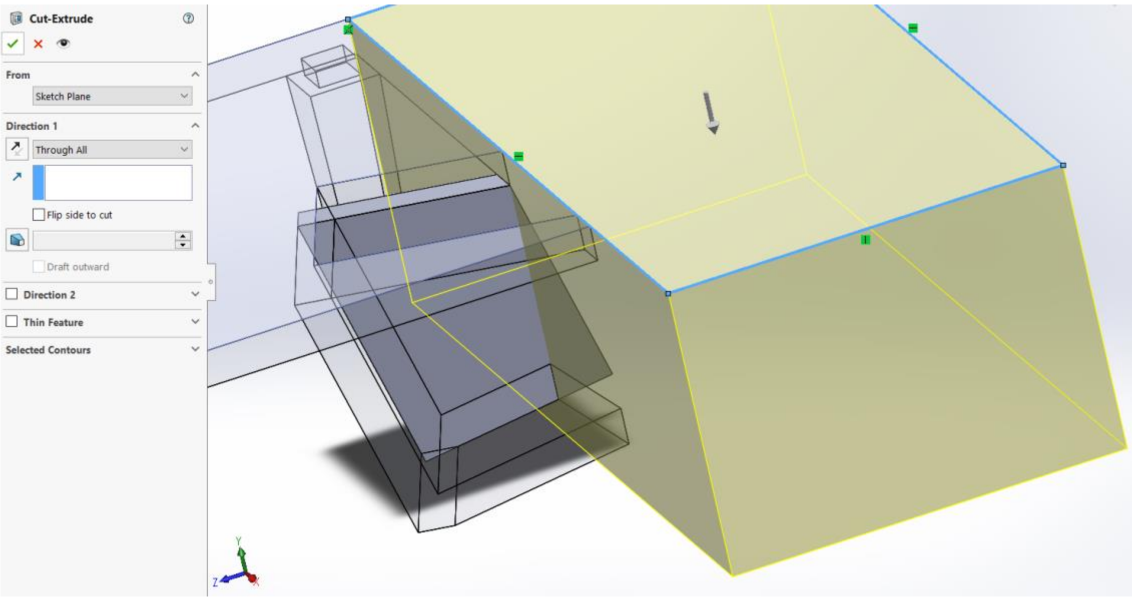


Figure 41. Excess parts need to be cut off.

Last step would be adding come connection bores with pins for pieces to match together, with necessary clearance. Joints are oversized because model will be printed in scale:

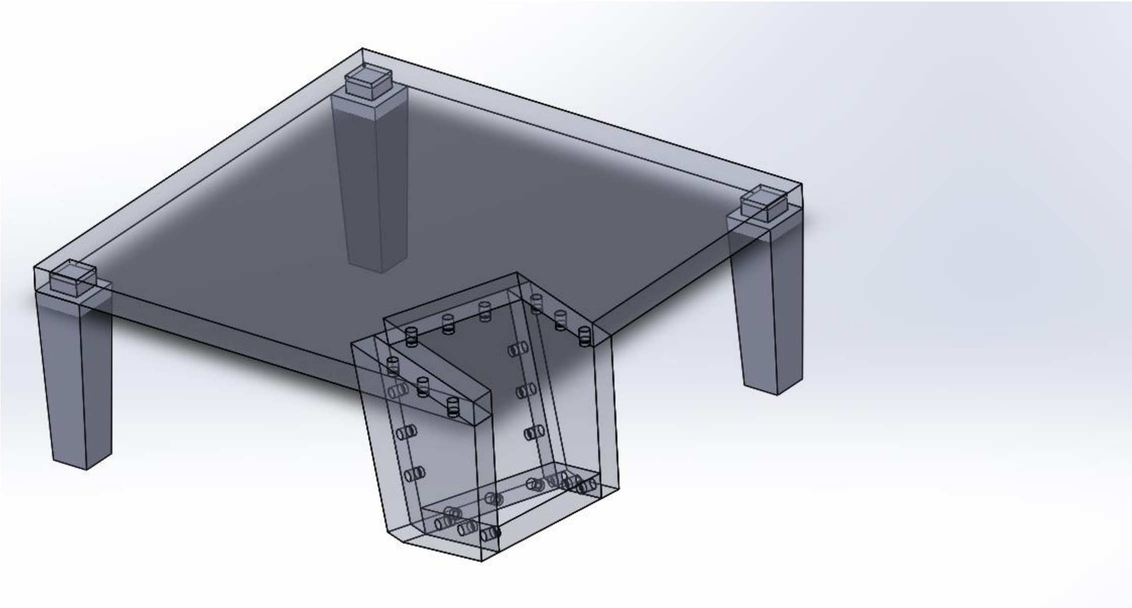


Figure 42. Connections added.

After that we have complete assembly, it will be ready for printing the consequent parts.

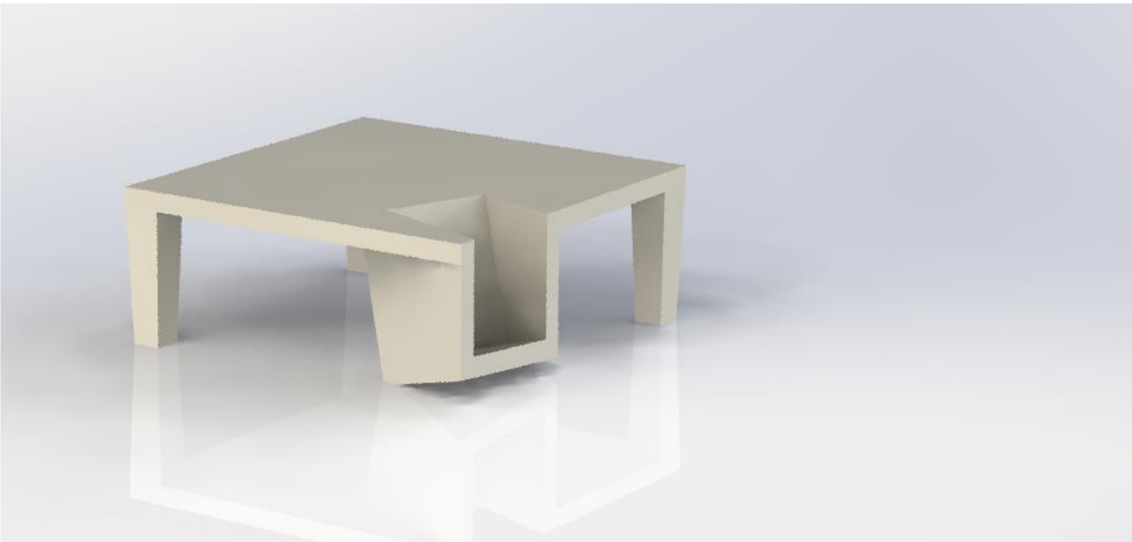


Figure 43. Final model.

TEACHING SPECIFICATION

How can this model be used in the classroom?

This exercise is designed to provide the student with the necessary knowledge on how to creatively model furniture for assembly – students need to rethink the assembly order while modelling parts.

What methodology can be used for its integration into the classroom/curriculum?

The table parts will be fully modeled / printed by each student, to a given standard or non-standard dimensions. The student will also have to determine the best printing orientation of parts – in order to minimize the waste of material. After printing and cleaning, the table should be cleaned and assembled

What benefits can be obtained with its use?

The students will learn about:

- Modeling of self-dependent shapes
- Modelling of fitting joint
- Details on positioning of a model, to save on support material.

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM, due to quality-price ratio of materials and machine.
Material	PLA recommended due to hygienic measures. ABS possible, not recommended due to thermal shrinking and deformation of a thin structure
Suitable dimensions for its use in the classroom (mm)	Here, it must be specified the necessary size of the object or model. You can indicate very general dimensions, such as length, height, width (x, y, z). Or it is also possible to provide more specific dimensions, like diameters, thickness, or the size of more specific parts of the object. It is recommended to indicate the measures in millimetres. On this part it is also convenient to consider the printing bed size. This will restrict the size of the object to print.
Should the piece be resistant or be subjected to stress?	Show model – no specific requirements, can be up to 2 mm walls with 20-30% infill
Number of pieces of which the exercise is composed:	Multiple pieces
Ensemble type if necessary (slot, clip, screwed ...)	Push-on assembly, some areas may need to be manually sanded to fit
Accuracy and definition required. (Quality) Low, mid or High.	Medium to high quality, visual appearance of the model is a key
Support material or post-processing.	Support material can be the same as printing material, removal and cleaning up models necessary

7. Exercise "Design of furniture with complex geometry in 3D printing"

INFORMATION

Exercise Name	Design of furniture with complex geometry in 3D printing
Specific Subject	Design of furniture with complex geometry which could be hard to prototype with other technology.
Number of pieces of which the model is composed	Single piece

3D MODEL DESCRIPTION

Written description.

The Panton Chair is a classic in the history of furniture – designed by Verner Panton in 1960, the chair was developed for serial production in collaboration with Vitra (1967).

It was the first chair made completely out of plastic in one single piece. Since its introduction to the market, it has advanced through several production phases. The first rather heavy model, which required substantial finishing work, was subsequently improved and adapted to industrial production using thermoplastic polystyrene which led to a marked reduction in cost. In 1968, Vitra initiated serial production of the final version which was sold by the Herman Miller Furniture Company. The material used was Baydur, a high-resilience polyurethane foam produced by Bayer in Leverkusen, Germany. It was offered in several colors.

However, in 1979, production was halted as it became apparent that polystyrene was not sufficiently durable and began to look shabby over time. Four years later, the model was again produced as the Panton Chair Classic, This time in the rather more expensive polyurethane structural foam. Finally, in 1999, Vitra used polypropylene for manufacturing the Panton Plastic Chair in a variety of colors.

Panton was a contributor to the development of sleek new styles reflecting the "Space Age" of the 1960s which became known as Pop Art. It is regarded as one of the masterpieces of the Danish design. The chair was included in the 2006 Danish Culture Canon.

Panton chair as it was total breakthrough in the 1960's, still has futuristic look, and is relatively complex to model and produce in traditional technologies. 3D modelling and 3D printing takes this structure from incredibly complex to moderately hard to model and easy to prototype.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

Panton chair is based only on lightly specified curves, no single straight line is present in the model

Figure 44. Panton chair.

Crucial to understand how to model it, is to use at least one photo sideview. We can apply also more views, like front or top view to match designed curvature.

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Figure 45. Panton chair sideview.

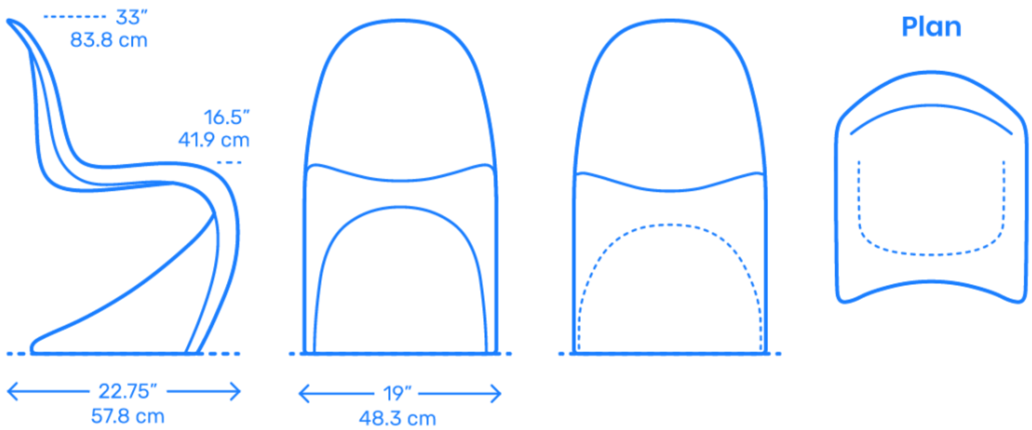


Figure 46. Panton chair dimensions [8].

Despite of the set dimensions of original model, it is relatively easy to scale model down or up to custom size, like for kids or population which doesn't fit standard dimensions.

Figure 47. Panton chair scaled down for kids.

Additional materials for a better description.

Model is based on the bottom line and edge line curves sketched on a picture, with edge curves and front view projected into 3d curve:

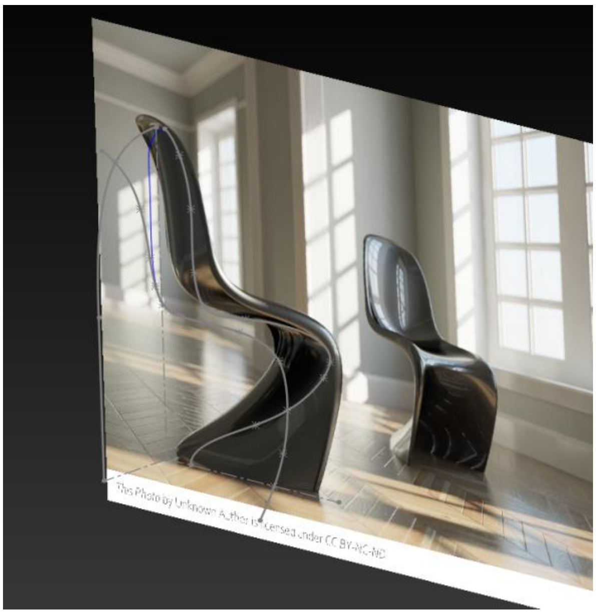


Figure 48. Bottom line and edge line curves, with projected blue curve of outer chair edge.

Then, you need to loft surface from projected curve into bottom curve, using 3d guides forming chair's seat:

Figure 49. Chair seat formed from projected and bottom curves.

Procedure can be repeat with outer bent strengthening edge – next projected curve:

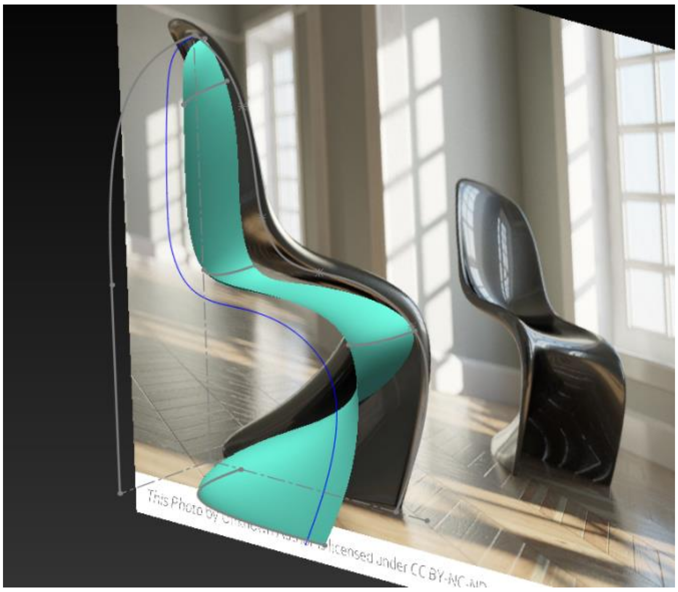


Figure 50. Projected curve of outer strengthening edge.

After creating of the curve – another lofted surface for edge:

Figure 51. Both surfaces created.

These faces need to be filleted, mirrored, and knit together:

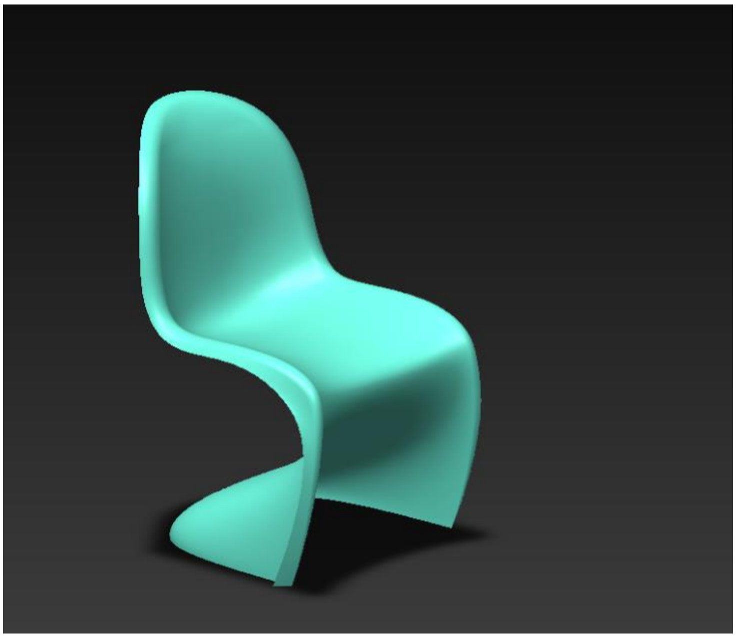


Figure 52. Joined, filleted, and mirrored faces into one final surface.

This final face needs to be thickened and sliced again, at least from the outer edge. Remember that depending on the final printing scale, you need to have a reasonable thickness, so final model has at least 1-2 mm to stay on one piece. If printing will be done in 1:5, this means thickening at least 10 mm.

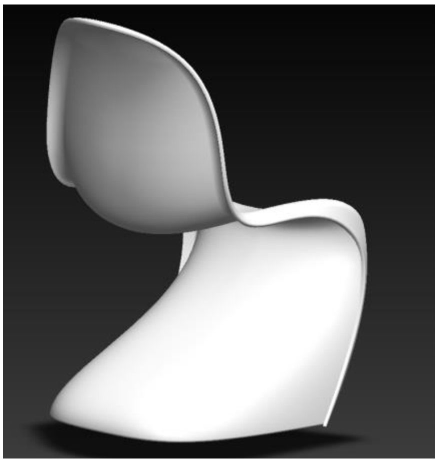


Figure 53. Thickened and filleted model.

Have a look to the final creation:

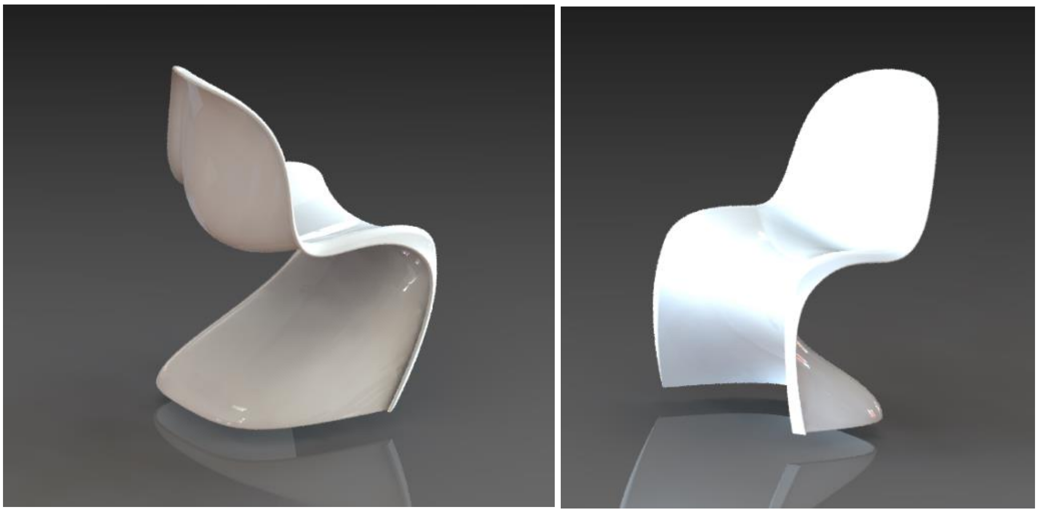


Figure 54. Final Panton chair model.

TEACHING SPECIFICATION

How can this model be used in the classroom?

This exercise is designed to provide the student with the necessary knowledge on how to creatively model complex furniture and scale it to required dimensions.

What methodology can be used for its integration into the classroom/curriculum?

The chair will be fully modeled / printed by each student, to a given standard or non-standard dimensions, basing on the pictures found on the internet. The student will also have to determine best printing orientation of a model – in order to minimize the waste of material.

What benefits can be obtained with its use?

The students will learn about:

- Self-sufficiency in finding out documentation necessary.
- Modeling of complex shapes.
- Surface modeling techniques.
- Details on positioning of a model, in order to save on support material.

TECHNICAL SPECIFICATION OF THE EXERCISE

TECHNICAL SPECIFICATIONS	
Technology	FDM, due to quality-price ratio of materials and machine.
Material	PLA recommended due to hygienic measures. ABS possible, not recommended due to thermal shrinking and deformation of a thin structure
Suitable dimensions for its use in the classroom (mm)	Here, it must be specified the necessary size of the object or model. You can indicate very general dimensions, such as length, height, width (x, y, z). Or it is also possible to give more specific dimensions, like diameters, thickness, or the size of more specific parts of the object. It is recommended to indicate the measures in millimeters. On this part it is also convenient to consider the printing bed size. This will restrict the size of the object to print.
Should the piece be resistant or be subjected to stress?	Show model – due to thin walls it needs to be printed with 100% infill
Number of pieces of which the exercise is composed:	Single piece
Ensemble type if necessary (slot, clip, screwed ...)	Not for assembly, single piece
Accuracy and definition required. (Quality) Low, mid or High.	Medium to high quality, visual appearance of the model is a key
Support material or post-processing.	Support material can be the same as printing material, removal and cleaning up model necessary

8. Exercise "Chair repair connectors"

INFORMATION

Exercise Name	Chair repair connectors
Specific Subject	Product Design, Sustainability
Number of pieces of which the model is composed	5 pieces

3D MODEL DESCRIPTION

Written description.

The exercise proposal is a joint that allows the reparation of chairs and stools that can no longer be used because they have cracks in the legs and support.
The joint has been designed to be easily inserted and adapted to any section, whether rounded, quadrangular, or rectangular. It can also be adjusted by means of a screw system so that it adapts to the size of the furniture in question.
The piece is composed of a main tubular part and various parts that fit into the main joint and modify the attachment according to the section of the chair leg. It is also possible to assemble pieces of chairs with different sections in such a way as to recover as much material as possible.
The whole piece is made up of 5 pieces and in particular a tubular joint and four reducers, two rectangular and two quadrangular.
The piece can be printed in various colors according to the object that needs to be repaired.
The general measures are 200 x 50 x 50 mm.
The main part will be connected to the reducers by means of an interlock. The reducers can be connected according to the dimension of the chair leg. The stool shall be assembled by interlocking and edged using screws which shall be placed in the holes.
The exercise in question has been designed to allow students of furniture and wood courses to focus on elements that can in a certain sense limit the waste of material and repair objects that would end up in landfills. In addition to the technical components that need to be developed, the design and adaptability to any chair and stool also provide elements of sustainability and recycling of materials and products.

The performance of the exercise will enhance and put into practice awareness on the use of different materials, recycling but also how to bring innovation to existing objects.

Statics lessons can also be combined to understand if the piece is resistant to the forces or forces on the joint.

The material that can be used for printing the piece is ABS or PLA. The use of ABS is recommended for the finished piece as it must be resistant to various forces.

Graphic Definition of the 3D Model. (Technical draws, hand free sketches and renders).

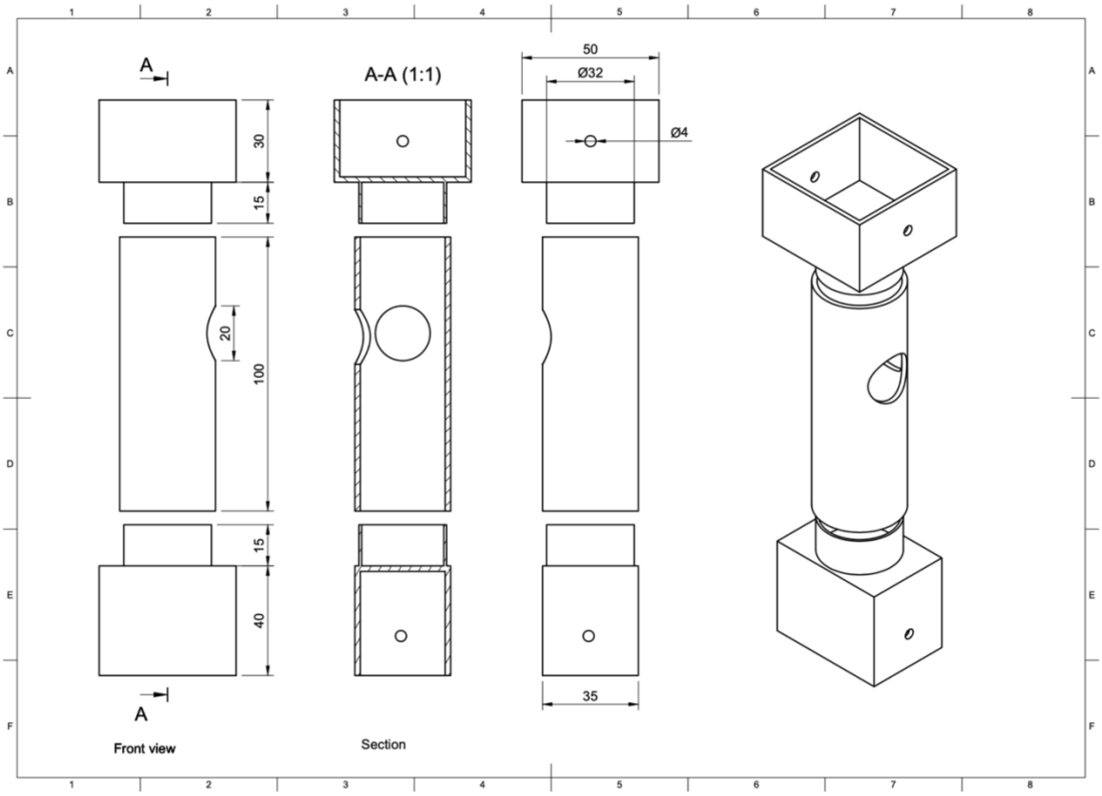


Figure 55: Schematic drawing of the model "Chair repair connectors".

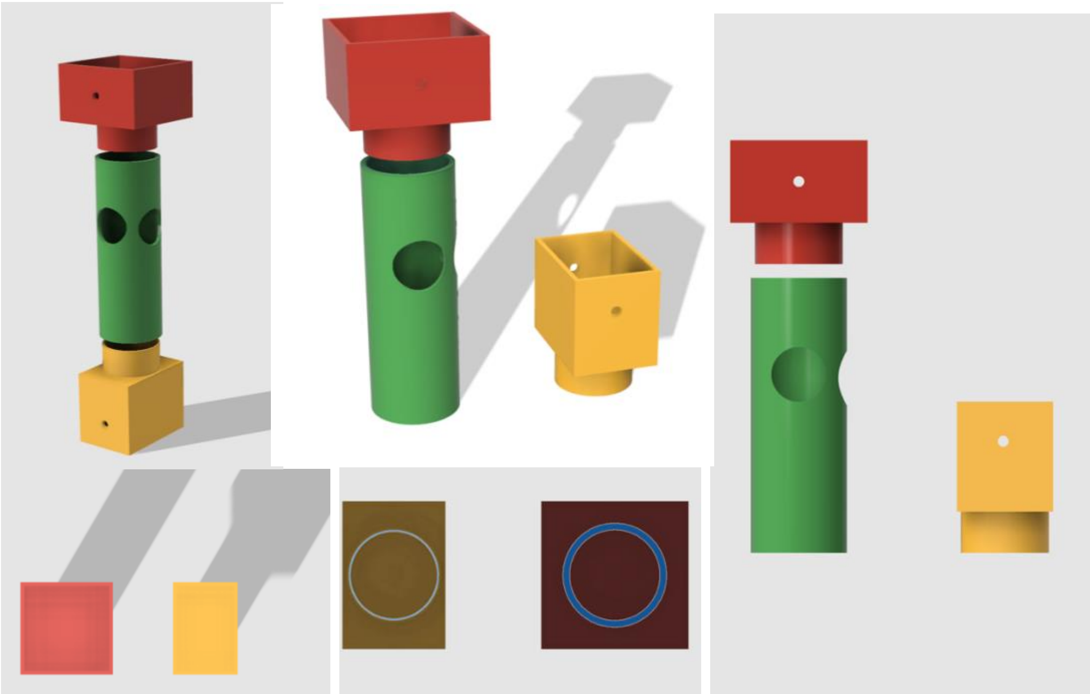


Figure 56: Renderings of the model "Chair repair connectors".

Additional materials for a better description.

Figure 57: Examples of similar products.

TEACHING SPECIFICATION

How can this model be used in the classroom?

The teacher in the classroom can both use the exercise to create eco-design workshops, focusing on how it is possible to reuse dismissed chairs and stools to give them a new life.

All this can be accompanied by technical drawing lessons, Life cycle assessment of the product but at the same time to create new joints with new sections for other types of furniture.
The main purpose is to make students to understand the reuse process and how with modern technologies it is possible to repair products that are now destined to be dismissed.
The lesson may focus on new ways of producing, using, and reusing industrial products, but also to record the new frontiers of conscious innovation on the issues of duration, circularity, sharing and services. The aim is precisely to investigate what has been done and is still being done around this issue.
It is also possible to focus the lesson on which products are simple and therefore more accessible, in what direction the repairability technologies are proceeding, how the strategies on spare parts, materials, projects of new aesthetics, etc. are studied. Without neglecting the programs that involve social issues and the territory, in view of the reconstruction of an economy that includes new logics of duration and repairability.

What methodology can be used for its integration into the classroom/curriculum?

To develop the exercise, the teacher will be able to use different teaching techniques. We suggest one, namely that of design thinking.

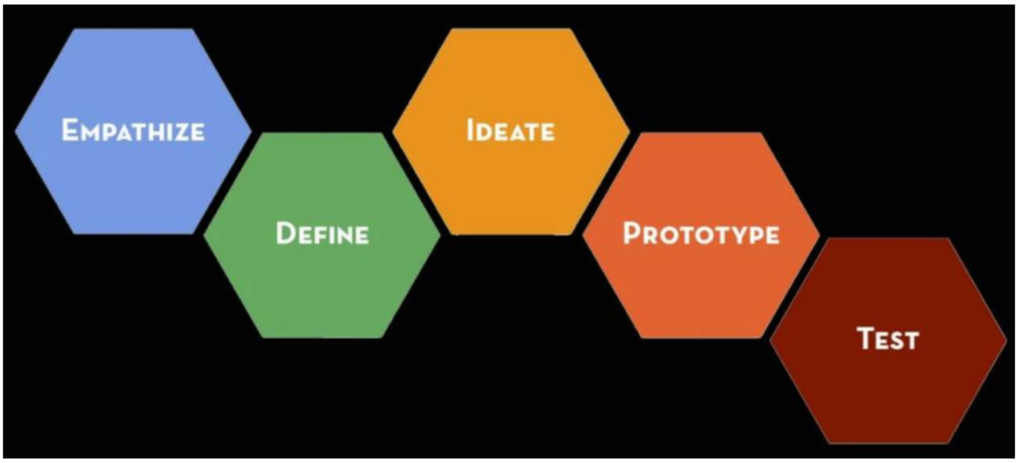


Figure 58: Design Thinking Methodology [9].

Through this process it is a matter of defining (the possible opportunity), developing the "prototype", comparing, improving, reaching, and finally achieving the project idea.
By adopting this approach in the classroom, students will be much more motivated and involved in carrying out the exercise itself and will develop infinite ideas for using the joint.

What benefits can be obtained with its use?

As evidenced many times, this exercise is multidisciplinary as by developing it various subjects can be taken into consideration and at the same time the student will be able to benefit in various fields. For example, thanks to the technical reproduction of the artefact, he will be able to learn how to draw a complex and geometric shape from life or technically on the PC.

Th student will also be able to understand how to build the joints and at the same time how to assemble pieces of different materials.

Furthermore, he will be able to learn the laws of statistics as he will have to test if the piece is resistant at the junction and load points of the object.

Then, there are all the aspects related to the recyclability and circularity of the subjects and the environmental protection that represent important notions to know and from which students can benefit.

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM
Material	ABS, PLA
Suitable dimensions for its use in the classroom (mm)	200 x 50 x 50 mm
Should the piece be resistant or be subjected to stress?	Yes
Number of pieces of which the exercise is composed:	5
Ensemble type if necessary (slot, clip, screwed ...)	Screw and pressure adjustments
Accuracy and definition required. (Quality) Low, mid or High.	Mid
Support material or post-processing.	It is necessary when removing the different supports.

9. Exercise "Furniture design with 3D printed connectors"

INFORMATION

Exercise Name	Furniture design with 3D printed connectors
Specific Subject	Furniture design, Carpentry, Prototypes.
Number of pieces of which the model is composed	7 pieces

3D MODEL DESCRIPTION

Written description.

The idea is to design 3D connectors for the manufacture of a three-legged low table, using them as an assembly system for the different parts that make up the piece of furniture.

There are several types of designs, as an example for the definition of the exercise the following is proposed:

Design of 7 connectors to be printed in 3D and used as a table assembly system:

- ⇒ 3 pieces to assemble the legs to the central reinforcement.
- ⇒ 1 piece for the central reinforcement to which the legs will be assembled.
- ⇒ 3 pieces to assemble the three legs to the seat.

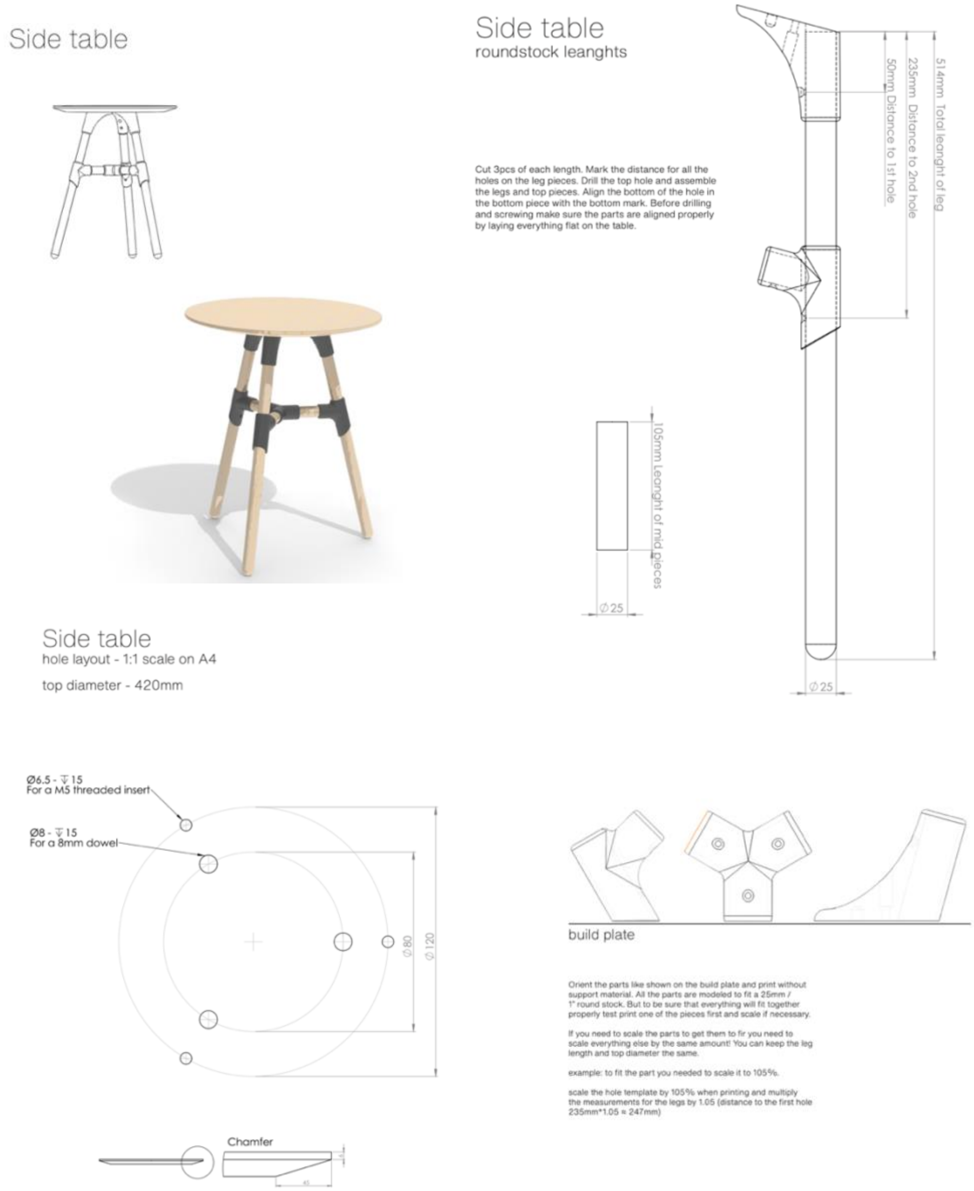
The colour and shape may vary depending on the designer's taste and skills.

This exercise aims to teach students how to integrate 3D printing into the furniture design and manufacturing process, showing them various options so that they can develop their creative thinking and knowledge of this technology while applying it to real and fully functional items.

The freedom of design and customisation in this type of exercise will provide the student with skills for future work.

The example of Alexandre Chappel can be used as a basis. The diagrams are shown in the following section.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).



In addition to the 3D printed parts, we need 15 screws, three pieces of wood for the legs of the height we want the table to be, three short pieces of wood for the central assembly that gives stability and rigidity to the table, and the tabletop.

Figure 59: 3D printed table [12].

Explanatory Video: *https://youtu.be/sPhhoWGFzKA*

Additional materials for a better description.

As a similar example, the following table is proposed. Source: *www.instructables.com*

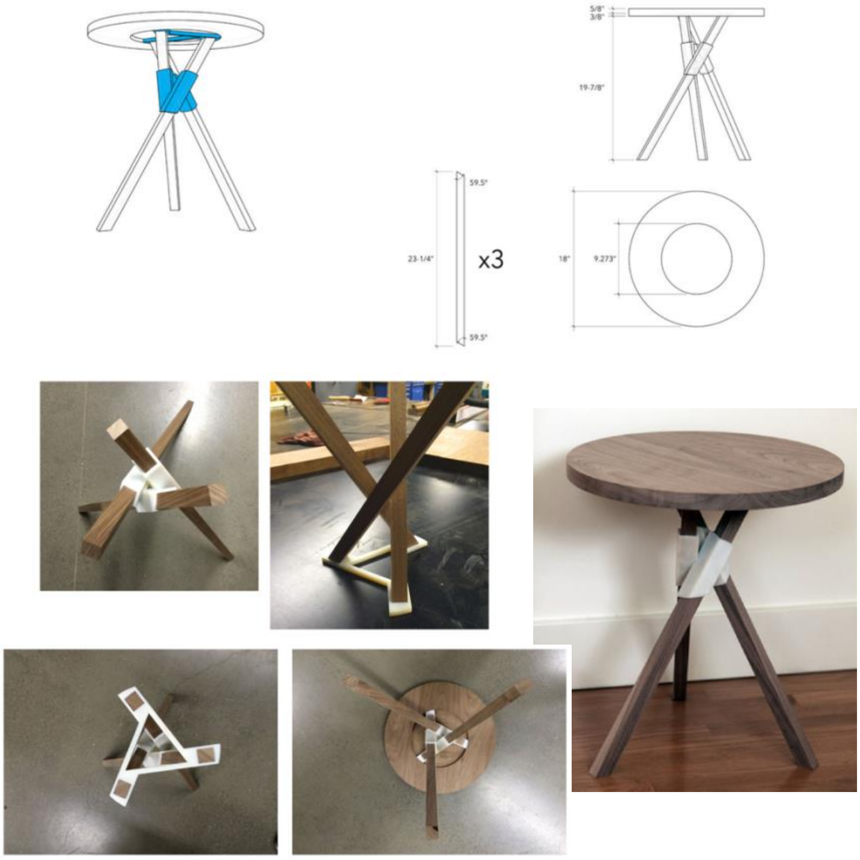


Figure 60: Tap Table [13].

TEACHING SPECIFICATION

How can this exercise be used in the classroom?

This exercise is designed to provide the student with the necessary knowledge to integrate 3D printing into the design and production of furniture. Through "hybrid technology" where traditional manufacturing and additive manufacturing merge, the student will explore the advantages and possibilities of integrating this technology into furniture production by learning by doing.

The aim is for the student to be able to use their knowledge of furniture design and manufacture to design connectors that will be 3D printed, and which will act as an assembly system in their furniture designs.

With this exercise the student will analyse and will be able to redesign if desired the assembly system to be 3D printed. With the printing of the connectors, the student will gain and expand knowledge about 3D technology: use and possibilities within the furniture and wood sector.

What methodology can be used for its integration into the classroom/curriculum?

An appropriate way to integrate this exercise into the classroom/curriculum would be to use a project-based methodology for the integration of 3D printing technology as a tool for the development of innovation and creativity in furniture design. This exercise can be performed in class as a multi-stage exercise:

- Design of a piece of furniture by designing and integrating 3D printed connectors as an assembly system.
- 3D printing of connectors and post-processing of parts where necessary.
- Preparation of the rest of the components (cutting and treatment of the different pieces of wood necessary for the manufacture of the table).
- Manufacturing process by means of assembly.
- Final analysis of the furniture and verification of its functionality.

Project-based learning is meaningful to students because they develop the skills necessary to develop their abilities in designing and integrating technology into their work. Within the framework of the technology project, students can pursue their own interests and work on customising their designs/prototypes/furniture.

What benefits can be obtained with its use?

To internalise the concept of a customised product. By modifying the design of the connectors, the student can create a multitude of table designs. The exercise will provide the student with more design opportunities and the possibility of making more complex structures.

This technique can be used both for final products such as the one in the exercise and for the manufacture of prototypes at a lower cost and production time.

Students could explore the differences and potential of traditional manufacturing techniques and additive manufacturing technologies, using the examples in class to facilitate an open-minded approach in design.

In terms of learning outputs, the learner will be able to:

- Analyze and optimize the design for 3D printing.
- Know the Influence of additive manufacturing on the design and prototyping of a product.

- Know how 3D printing is being used in the furniture market.
- Acquires knowledge about competitiveness of the additive manufacturing in the production sector.
- Work with hybrid technology (Pieces of wood assembled with 3D printing parts).

Generally speaking, the students tend to work with subtractive manufacturing, i.e. an object is created by removing material and waste is generated. This factor disappears with additive manufacturing. As the final object is created layer by layer and only the material required for the desired volume is consumed. The result is zero waste or a considerable reduction of waste. This new way of production will open the student's mind and help to reconcile with the environment.

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM
Material	PLA
Suitable dimensions for its use in the classroom (mm)	They will depend on the final design. They will be able to be printed without problems on the printing bed.
Should the piece be resistant or be subjected to stress?	Yes
Number of pieces of which the exercise is composed:	The number of parts will depend on the final design, 7 are specified in the example.
Ensemble type if necessary (slot, clip, screwed ...)	These printed parts act as connectors for the assembly of a wooden table, so some tolerances may be needed when printing them.
Accuracy and definition required. (Quality) Low, mid or High.	Mid or High
Support material or post-processing.	If the angles do not exceed 45° no support material is required. Sanding will be applied as post-processing to remove possible imperfections.

10. Exercise "Furniture design with 3D printed parts"

INFORMATION

Exercise Name	Furniture design with 3D printed parts
Specific Subject	Bring more colour and different materials to your design.
Number of pieces of which the model is composed	2 pieces or more

3D MODEL DESCRIPTION

Written description.

The idea is to integrate 3D printed parts in the design of a cabin. To bring more color and different materials into the design.

Design two parts to connect the legs of the cabin.

The colour and shape may vary depending on the designer's taste and skills.

With this exercise we aim to raise awareness in our students about new materials.
In this way, they discover that 3D printing will give them even more design freedom. In some cases, the use of wood as a raw material can come together with some limitations that can be also reduced or removed by using 3D printing. This also ensures that new materials become familiar to the student.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

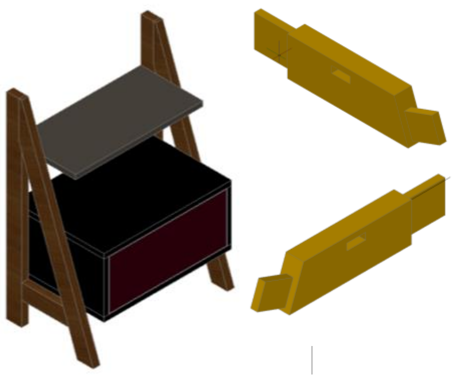


Figure 61: Rendering of the exercise "Furniture design with 3D printed parts".

Additional materials for a better description.

In addition to the 3D printed parts, we also need the other parts which will be made of wood. And will be manufactured in the different lessons.

There are other parts that can also be 3D printed. Depending on the size of the 3D printer but also on the design of the student.

TEACHING SPECIFICATION

How can this model be used in the classroom?

The exercise is intended to be put into practice in wood training at EQF level 4 of vocational training. Every student will manufacture this cabinet. The students must first draw each part themselves before they can start making. These also ensures that each student can design the connectors according to his own preference. And then later can have it printed in color in the material of your choice. To then, during the assembly of all parts, add these pieces to all parts that were manufactured in wood.

What methodology can be used for its integration into the classroom/curriculum?

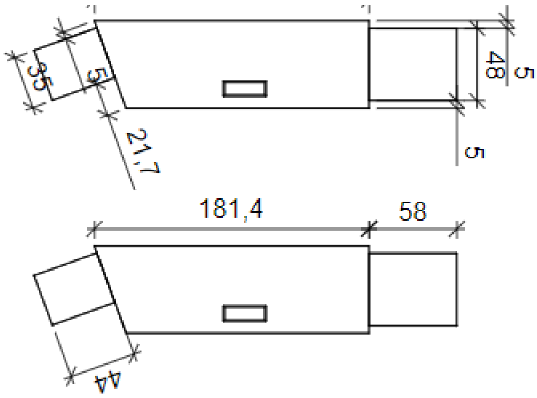
The workpiece will be made by each student. The students will learn new connection techniques and will be able to print the parts in 3D.

Before all parts are made, the workpiece must first be fully drawn.

What benefits can be obtained with its use?

The students do not only learn to work with wood but can combine different materials. Get to know new techniques.

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM
Material	PLA is very easy to print, very accurate and rigid, so it is one of the options more frequent for printing models. ABS is a bit more complicated to print because it tends to deform.
Suitable dimensions for its use in the classroom (mm)	
Should the piece be resistant or be subjected to stress?	Yes, the part will experience forces. The part should hold the ben of the cabinet together. And will be glued with the legs.
Number of pieces of which the exercise is composed:	There's a minimum of 2 pieces
Ensemble type if necessary (slot, clip, screwed ...)	Pin hole connection. By designing the piece, the drawing has to be perfect. So the connecting can be made.
Accuracy and definition required. (Quality) Low, mid or High.	Low quality can work for this part. The higher the quality, the more attractive the workpiece will be. The part is also clearly visible in the whole.
Support material or post-processing.	No supporting material will be required.

11. Exercise "Chair design with 3D printed connectors and simple wooden elements"

INFORMATION

Exercise Name	Chair design with 3D printed connectors and simple wooden elements
Specific Subject	Chair design, Carpentry, 3D printing, bonding wood to PLA, Prototypes.
Number of pieces of which the model is composed	Six 3d printed pieces

3D MODEL DESCRIPTION

Written description.

The idea is to design a chair using 3D printed connectors and simple wooden elements (which could be bought/prepared in ordinary DIY shop), bonded together with selected adhesive.

Simple wooden elements (square, rectangular, shapes and panels) are proposed, since not all schools have additional woodworking machinery to machine more complex parts. There are different options of design of connectors, depend on the level of modelling skills and available machinery for wood preparation. The basic limitations for chair design should be basic chair dimensions:

- Seat height 450-470 mm
- Seat slope angle 0-5°
- Seat width min 380 mm
- Backrest height 100 mm
- Backrest angle (from horizontal plane) 95-110 °
- Seat depth 400-440 mm
- Distance between seat and lower edge of backrest 210 mm

Figure 62: Schematic drawing of the chair.

Several types of designs are possible. The simplest consist on:

- ⇒ 6 different 3d printed connectors,
- ⇒ 4 wooden legs,
- ⇒ 4 wooden stretchers,
- ⇒ 2 wooden backrest parts and
- ⇒ panels for seat and backrest.

The colour and shape of chair and connectors may vary depending on the designer's taste and skills. This exercise aims to teach students how to integrate 3D printing into the furniture design and manufacturing process, showing them various options so that they can develop their creative thinking and knowledge of this technology while applying it to real and fully functional items. Also, by including wooden elements, we could use smaller connectors and thus could chair be printed on smaller 3D printers.

The freedom of design and customisation in this type of exercise will provide the student with skills for future work.

The example below can be used as a basis. The diagrams are shown in the following section.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

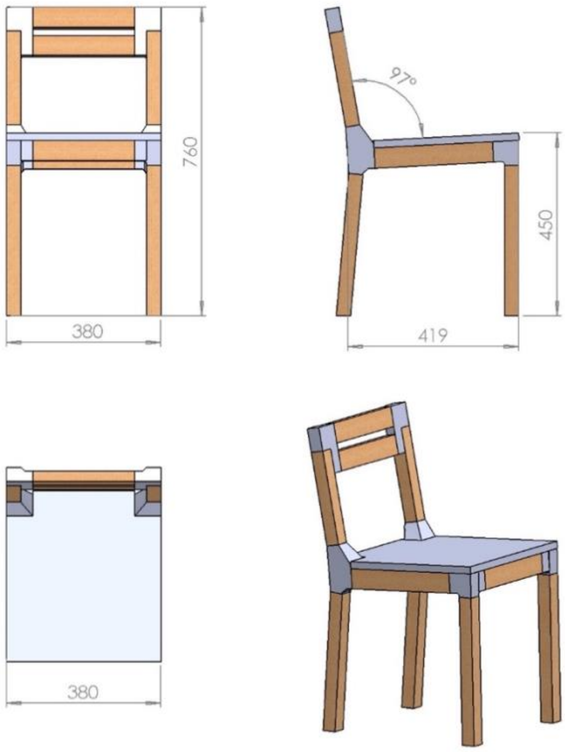


Figure 63: Chair with 3d printed connectors.

In addition to the 3D printed and wooden parts we need 4 screws (connecting the seat to stretchers) and adhesive for bonding connectors and wooden parts.

Additional materials for a better description.

If additional woodworking machines are available, the design could be more complex, for example:

Figure 64: chair with 3d printed connectors [14].

Figure 65: chair with 3d printed connectors [15].

TEACHING SPECIFICATION

How can this exercise be used in the classroom?

This exercise is designed to provide the student with the necessary knowledge to integrate 3D printing into the design and production of furniture.

The aim is for the student to be able to use their knowledge of furniture design and manufacture to design connectors that will be 3D. These 3D printed elements, together with wooden elements will act as an assembly system in their furniture designs.

During the design phase, the student needs to take into consideration chair dimensions, the limitation of use of simple wooden elements, provide sufficiently strong connectors (selection of materials, wall thickness, infill, enough area for bonding), optimize construction (mid/bottom additional stretchers, additional diagonal connectors) and select appropriate adhesive for bonding.

What methodology can be used for its integration into the classroom/curriculum?

This exercise can be performed in class as a multi-stage exercise:

- Study of the existing chairs and their versions with 3d printed connectors.
- Design of a piece of furniture by designing and integrating 3D printed connectors as an assembly system.
- 3D printing of connectors and post-processing of parts where necessary.
- Selecting appropriate adhesive option by testing different adhesives for bond strength of the 3d printed wooden parts.
- Selecting appropriate connections- adhesive/screws, snap fit.

- Preparation of the rest of the components (cutting and treatment of the different pieces of wood necessary for the manufacture of the table).
- Manufacturing process by means of assembly.
- Final analysis of the furniture and verification of its functionality.

The students will develop designing skills of furniture with 3d printed elements and awareness of different technologies (woodworking and 3D printing) and how to combine them to get both to design functional product.

What benefits can be obtained with its use?

Thinking about design from different materials and their properties. How to incorporate different materials to functional product. Understanding customer wishes and limitations in the design phase. Understanding 3d printing technology- effect of material selection, printing orientation, connections to form bigger objects.

In terms of learning outputs, the learner will be able to:

- Analyse and optimise the design for 3D printing.
- Knows the Influence of additive manufacturing on the design and prototyping of a product.
- Knows how 3D printing is being used in the furniture market.
- Acquires knowledge about competitiveness of the additive manufacturing in the production sector.
- Work with hybrid technology (Pieces of wood assembled with 3D printing parts).

- Understanding material selection, printing orientation to achieve full strength of connectors.Understand loading on seating chair and how to design connectors to withstand these forces -exercise could be extended to testing phase: chair could be tested according to standard EN 1729-2 Furniture - Chairs and tables for educational institutions - Part 2: Safety requirements and test methods. Or just a part of the chair, front connector could be tested on universal testing machine to compare different connector designs:

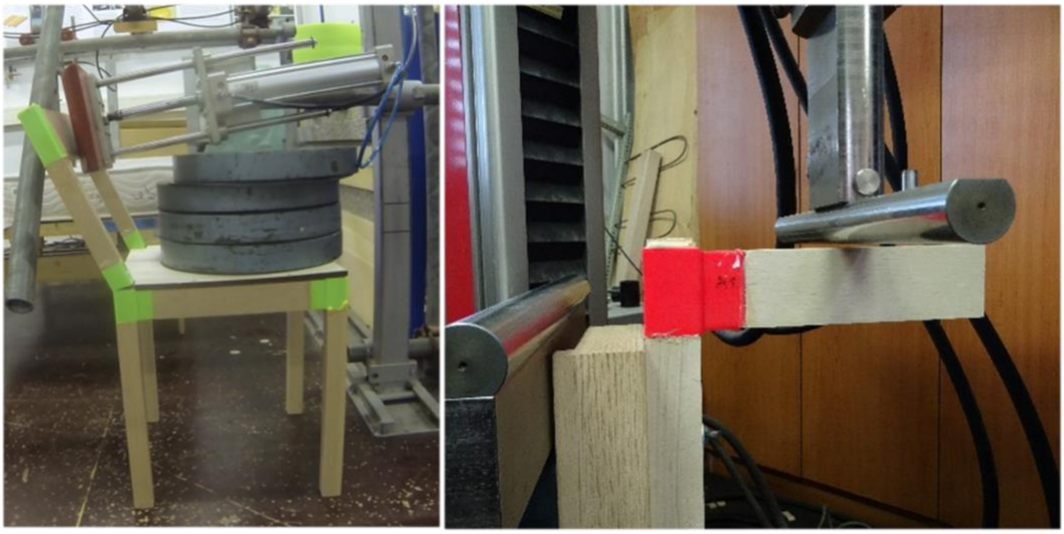


Figure 66: chair testing according to standard EN 1729- left; connector testing – right.

Advanced option 1: loading simulations, numerical simulations, FEA analysis.

- *https://youtu.be/lG_oSSo9vak*

Advanced option 2: Topology study.

- *https://youtu.be/KjbnzZ6D4dc*

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM
Material	PLA, PETG, ABS (if appropriate printer is available)
Suitable dimensions for its use in the classroom (mm)	They will depend on the final design. They will be able to be printed without problems on the printing bed.
Should the piece be resistant or be subjected to stress?	Yes
Number of pieces of which the exercise is composed:	The number of parts will depend on the final design, 6 are specified in the example.
Ensemble type if necessary (slot, clip, screwed ...)	These printed parts act as connectors for the assembly of a wooden table, so some tolerances may be needed when printing them. Also, bonding is required with selected adhesive or selection of right screws.
Accuracy and definition required. (Quality) Low, mid or High.	Mid or High
Support material or post-processing.	If the angles do not exceed 45° no support material is required. Sanding will be applied as post-processing to remove possible imperfections.

12. Exercise "Parametric design of 3D printed furniture-meeting ergonomics and standard requirements"

INFORMATION

Exercise Name	School chair design for different age of kids
Specific Subject	Chair design, Carpentry, 3D printing, Prototypes, standards, ergonomy.
Number of pieces of which the model is composed	6 3d printed pieces

3D MODEL DESCRIPTION

Written description.

With 3d printing and digital models its even easier to manufacture products tailored to each customer or standard requirements. The goal is to prepare a parametric model of school chair with 3d printed connectors, which could serve as a base for all chair sizes, proposed in standard EN 1729: Furniture - Chairs and tables for educational institutions - Part 1: Functional dimensions.
For a basic model could work the model design in previous lesson: "Chair design with 3D printed connectors and simple wooden elements".

When tailoring the product to different standard or customer requirements, not just the product dimensions need to be changed. It is also necessary to think about 3d printing- setting the dimensions of connectors, wall thickness, printing parameters, and dimensions of all components-depending on its mechanical properties and expected loading.

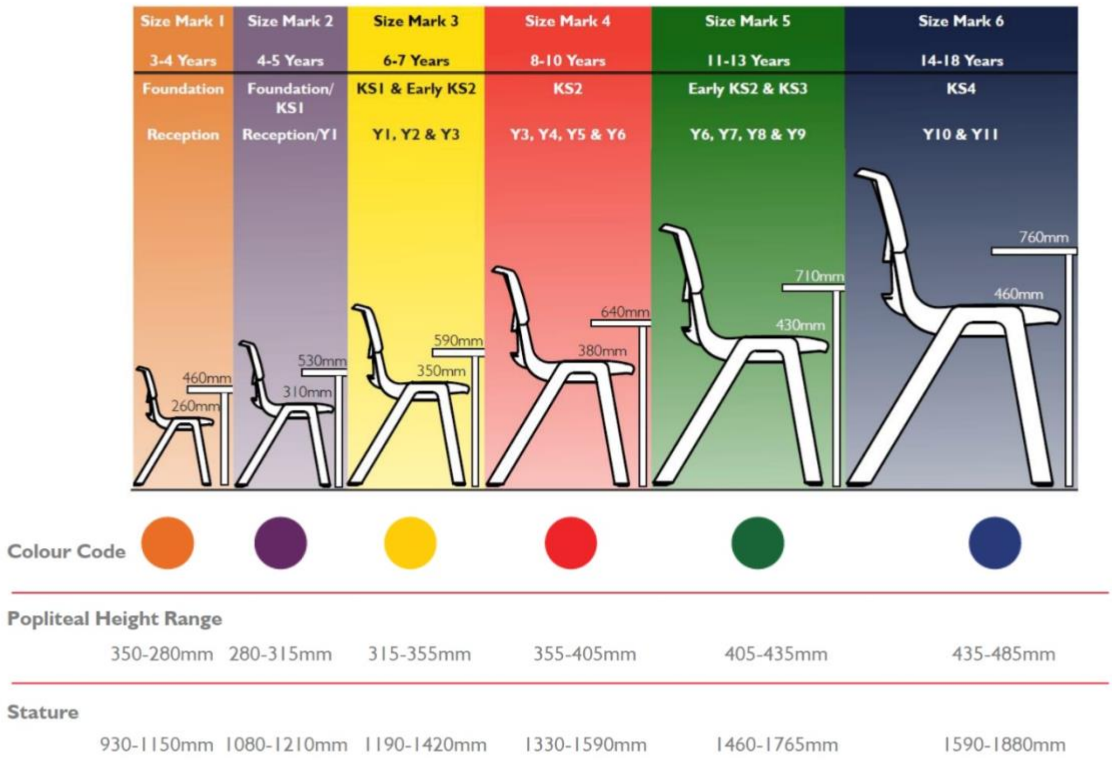


Figure 67: School/kindergarten chair dimensions according to standard EN 1729 [10].

Basic design of chair could be obtained from previous exercise-design of chair with 3d printed connectors.

The basic limitations should be basic chair dimensions for each age class:

Table 1: dimensions for each age class

Chair size mark	0	1	2	3	4	5	6
Colour code	white	orange	purple	yellow	red	green	blue
K Popliteal range (without shoes)	200-250	250-280	280-315	315- -355	355- -405	405- -435	435- -485
V Stature range (without shoes)	800--950	930- -1160	1080- --1210	1190-1420	1330- -1590	1460- -1765	1590- -1880
h8 height of seat ±10 mm	210	260	310	350	380	430	460
t4 depth of seat ±10 mm (0-2) ±20 mm (3-7)	225	250	270	300	340	380	420
b3 min. seat width	210	240	280	320	340	360	380
t7 depth seat surface (min)	actual t4 minus 20 mm						

h6 height of point S -10 to +20 mm	140	150	160	180	190	200	210
h7 backrest height min.							
b4 min. width of backrest	-	210	250	270	270	300	330
r min. horizontal radius of backrest	-	300	300	300	300	300	300
β inclination of backrest	-						
α inclination of the seat max							
h1 height, top ± 10	400	460	530	590	640	710	765
t1 min. depth of top		500	500	500	500	500	500

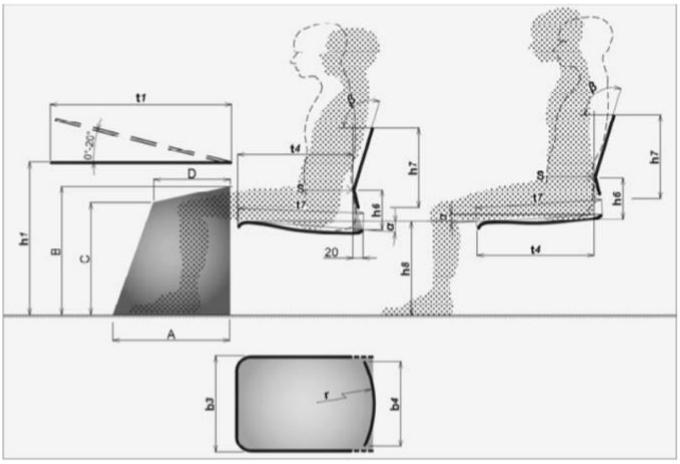


Figure 68: Dimensions of tables and chairs. School (Source: School and Health 21, 2011, Health Literacy through Education Requirements for chairs and tables for educational institutions).

Recommendations to 3D print the connectors:

- Wall thickness: for smaller chairs (like for mark 0-2), 3 mm, for bigger chairs at least 4mm of solid walls
- Infill: at least 40%
- Material: PLA, PETG
- Dimensions of wooden parts: for smaller chairs (like for mark 0-2), cross section at least 25x25 mm, for bigger chairs at least 35x35 mm.

The colour and shape of the chair and the connectors may vary depending on the designer's taste and skills. If the standard is strictly following - chairs need to be marked with colour code for each age size-colours in the top row of the table.

This exercise aims to teach students how to integrate 3D printing and parametric design into the furniture design and manufacturing process and emphasizing the need for considering 3d printing limitations.

The exercise could be then extended to study the standard requirements for strength and durability and testing the chairs. Tests could be done either in real laboratory or by simulations in CAD programs. For more information about strength loading test look for standard EN 1729-2 Furniture - Chairs and tables for educational institutions - Part 2: Safety requirements and test methods.

The example below can be used as a basis. The diagrams are shown in the following section.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

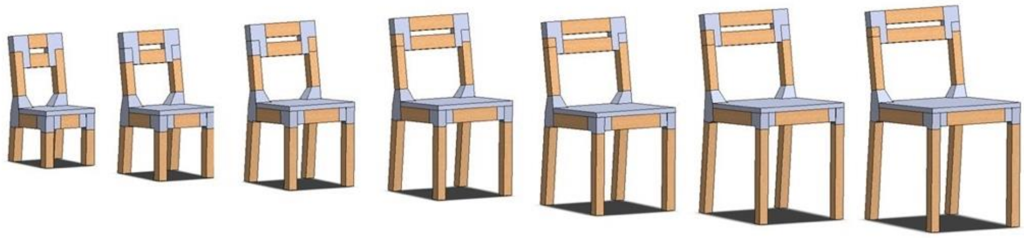


Figure 69: Different sizes of the adaptable chair.

Additional materials for a better description.

Example of different sizes of school chairs (not necessarily 3d printed)

Figure 70: Different sizes of school chairs [16].

TEACHING SPECIFICATION

How can this exercise be used in the classroom?

This exercise is designed to encourage the student to think about tailoring product to different customers or to follow the standard requirements connected with ergonomic, dimensions, safety requirements.

The aim is for the student to be able to use their knowledge of furniture design and manufacture for designing connectors that could be parametrically adjusted to different customers, with regard also to 3D printing requirements and properties.

During the design phase, the student needs to take into consideration the dimensions, the limitation of use of simple wooden elements, provide sufficiently strong connectors (selection of materials, wall thickness, infill, enough area for bonding), optimize construction (mid/bottom additional stretchers, additional diagonal connectors) and select appropriate connection technique.

What methodology can be used for its integration into the classroom/curriculum?

This exercise can be worked on in class as a multi-stage exercise:

- Study of the existing chairs and their version with 3d printed connectors.
- Design of a piece of furniture by designing and integrating 3D printed connectors as an assembly system.
- Optimising connectors for parametric design.
- 3D printing of connectors and post-processing of parts where necessary.
- Selecting appropriate adhesive- option testing different adhesives for bond strength wood-3d printed parts.
- Preparation of the rest of the components (cutting and treatment of the different pieces of wood necessary for the manufacture of the table).
- Manufacturing process by means of assembly.
- Final analysis of the furniture and verification of its functionality/ possible strength testing

Project-based learning is meaningful to students because they develop the necessary skills to develop their abilities in designing and integrating technology into their work. Within the framework of the technology project, students can pursue their own interests and work on customising their designs/prototypes/furniture.

- Understand possibilities of tailoring the product to each user

- Know how 3D printing is being used in the furniture market.
- Acquire knowledge about competitiveness of the additive manufacturing in the production sector.
- Work with hybrid technology (Pieces of wood assembled with 3D printing parts).

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM
Material	PLA, PETG, ABS (if appropriate printer is available)
Suitable dimensions for its use in the classroom (mm)	They will depend on the final design. They will be able to be printed without problems on the printing bed.
Should the piece be resistant or be subjected to stress?	Yes
Number of pieces of which the exercise is composed:	The number of parts will depend on the final design, 6 are specified in the example.
Ensemble type if necessary (slot, clip, screwed ...)	The printed parts act as connectors for the assembly of a wooden table, so some tolerances may be needed when printing them. Also, bonding is required with the selected adhesive.
Accuracy and definition required. (Quality) Low, mid or High.	Mid or High
Support material or post-processing.	If the angles do not exceed 45° no support material is required. Sanding will be applied as post-processing to remove possible imperfections.

13. Exercise "Assembled Pieces for furniture design"

INFORMATION

Exercise Name	Assembled Pieces for furniture design
Specific Subject	Furniture design, Carpentry, Prototypes.
Number of pieces of which the model is composed	14 pieces

3D MODEL DESCRIPTION

Written description.

The main aim of this exercise is to facilitate in the classroom an open approach for furniture design and prototyping using 3D printing as a manufacturing tool.
The assembled parts exercise is composed of several parts showing the most common types of assemblies in wood furniture making. Four models are presented. All types show a repeating pattern that, when assembled, appears to create an inseparable joint.

The models are as follows:
1. Dovetail: The basic geometry of this model is a cube, divided in two halves. One half has two protrusions that are formed like the classic dovetail in carpentry (but distorted). The other half has two cavities that are also formed like the dovetail. These two halves create a connection, which can only be loosened by pushing the two parts in the right directions. There is only one possible axis that allows movement (forwards and backwards, thus two directions). This axis is parallel to the axis along which the cavities and protrusions are oriented and constructed.
2. Pentagon: This model is a variation of the dovetail. Here the two halves show a pentagonal shape, and apart from that it follows the same construction principles as the Dovetail.
3. Triangular dovetail: The two halves form an equilateral triangle which can only be loosened by rotating the triangle and then separating the parts. Here the pattern is rotated around the z-axis and intersects with the triangular body.
4. E-shaped pattern with various types of assemblies. It is intended to show five different assemblies that together form a single element. These assemblies are:

- Dovetail.

- Double tongue and groove.
- Cross-shaped mortise and tenon assembly.
- Mortise and tenon assembly.
- Half-Lap assembly with through bolt.

This exercise aims to teach students how to integrate 3D printing into the furniture design and manufacturing process, showing them various options which will allow them to develop their creative thinking and knowledge of this technology while applying it to real and fully functional items.

The freedom of design and customisation in this type of exercise will provide students with skills for their future work, where they can integrate additive manufacturing as a method for making customised furniture and prototypes.

Graphic Definition of the 3D Model. (Technical draws, hand free sketch and renders).

The models can be printed in different scales and layer thicknesses according to the needs (printing time, finishing quality, final use...).
The following images show the pieces designed for this exercise:

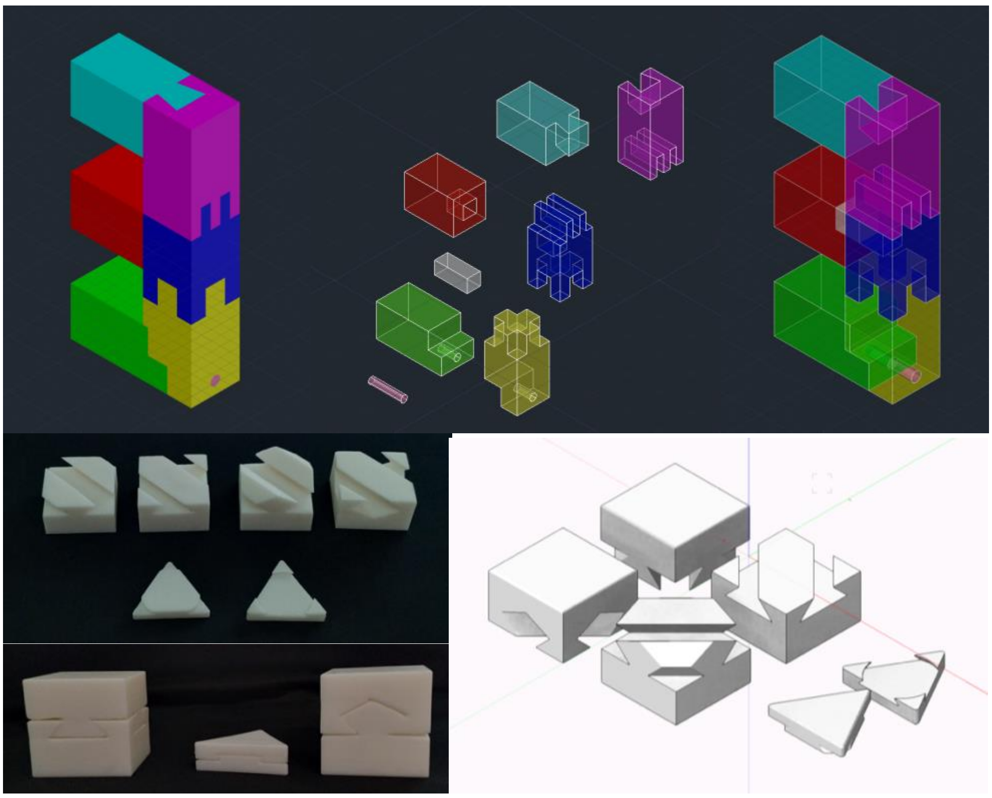


Figure 71: Models of the "Assembled Pieces for furniture design" exercise.

Additional materials for a better description.

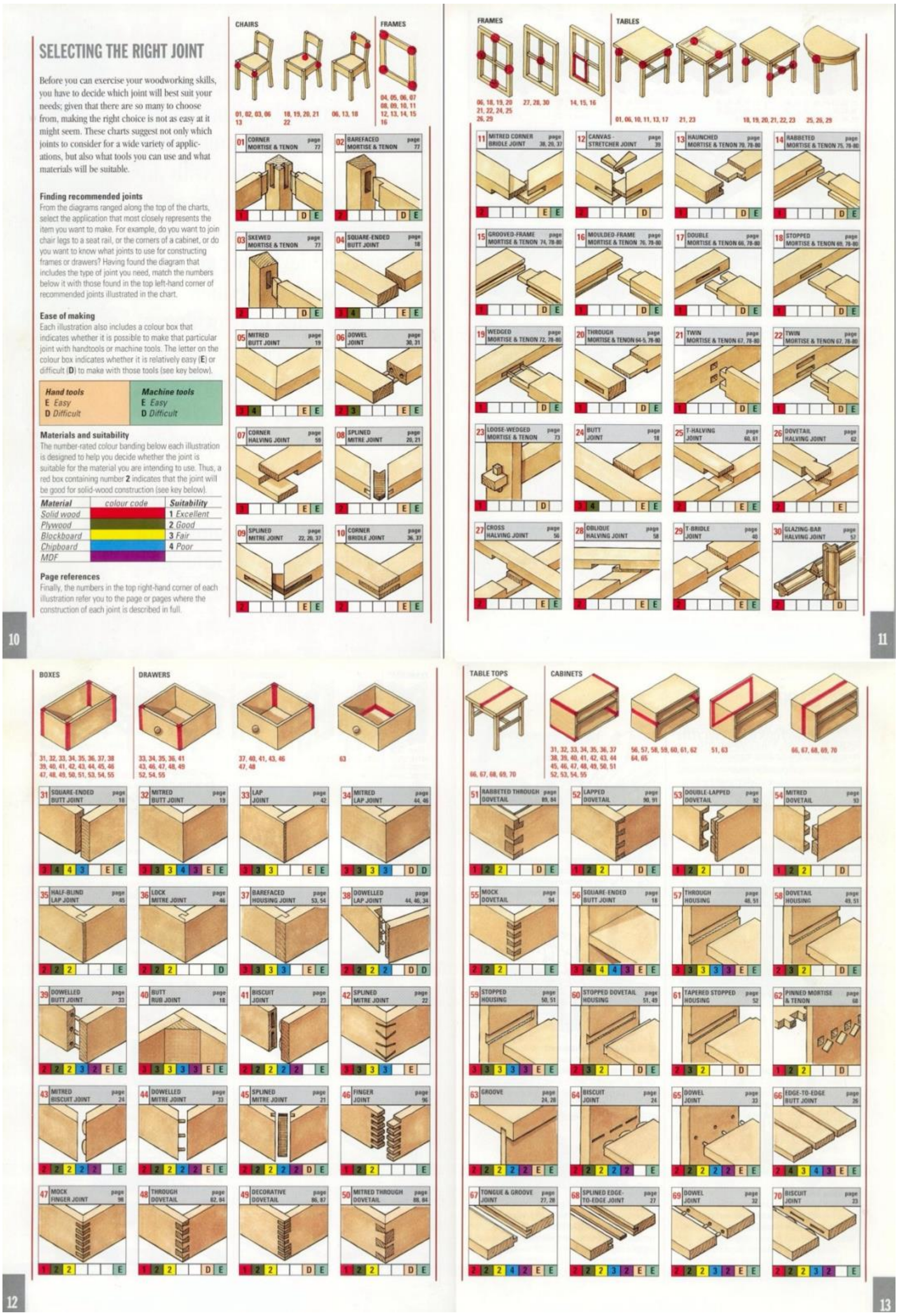


Figure 72: Joint for wood manufacturing *[11]*.

TEACHING SPECIFICATION

How can this exercise be used in the classroom?

This exercise is designed to provide the student with the necessary skills to integrate 3D printing into furniture design and production.

With the knowledge of the different types of joints that can be used to assemble the different parts that make up a piece of furniture, the student can create their designs to be fully 3D printed. These joints make possible to create larger pieces by assembling several parts, or even to put hybrid technology (traditional manufacturing with 3D printed parts) into practice.

The aim is to allow students to use their knowledge in furniture design and manufacturing to design furniture for 3D printing.
With this exercise the student will analyse and be able to redesign if desired the assembly system to be 3D printed. With the printing and use of this type of assemblies, the student will acquire and expand knowledge about 3D technology: use and possibilities within the furniture and wood sector.

Students will be able to understand the geometrical principles that make this connection possible. An open approach to design should be facilitated. In time, they should be able to design their own models, customised and adapted to the needs of each design.

In addition, the students can use the principle of the connection to test their design on a smaller scale by designing their prototypes using this kind of easy assembly. In this case, students could explore the differences and potentials of both traditional manufacturing techniques and additive manufacturing technologies.

What methodology can be used for its integration into the classroom/curriculum?

An appropriate way to integrate this exercise into the classroom/curriculum would be the project-based methodology for the integration of 3D printing technology as a tool for the development of innovation and creativity in furniture design. This exercise can be deployed in class as a multi-stage exercise:

- Observation of the models designed in this exercise.
- Analysis of the different types of assemblies: resistance, functionality, applications...

- Integrate these assemblies into your personal design.
- Create new assemblies and apply them to furniture prototypes. Final analysis of the furniture and verification of its functionality.

Project-based learning is meaningful to students because they develop the necessary skills to develop their abilities in designing and integrating technology into their work. Within the framework of the technology project, students can pursue their own interests and work on customising their designs/prototypes/furniture.

What benefits can be obtained with its use?

To internalise the concept of a personalised product. By modifying the design of the assemblies or integrating those proposed in this exercise, the student can create a multitude of furniture designs. This technique can be used for both final products and prototyping with reduced cost and production time.

Students could explore the differences and potential of traditional manufacturing techniques and additive manufacturing technologies, using the examples in class to facilitate an open approach to design.

In terms of learning outcomes, the student will be able to

- Analyse and optimise design for 3D printing.
- Know the influence of additive manufacturing on the design and prototyping of a product.
- Know the use of 3D printing in the furniture market.
- Acquire knowledge about the competitiveness of additive manufacturing in the production sector.
- Work with hybrid technology (wooden parts assembled with 3D printing parts).

The students of the woodworking and furniture sector tend to work with subtractive manufacturing, i.e., an object is created by removing material and waste is generated. This factor disappears with additive manufacturing, as the final object is created layer by layer and only the material required for the desired volume is consumed. The result is zero waste or a considerable reduction of waste. This new way of production will open the student's mind and help to reconcile with the environment.

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM
Material	PLA
Suitable dimensions for its use in the classroom (mm)	They will depend on the final design. They will be able to be printed without problems on the printing bed.
Should the piece be resistant or be subjected to stress?	Yes
Number of pieces of which the exercise is composed:	The number of pieces to show all the models in this exercise is 14.
Ensemble type if necessary (slot, clip, screwed ...)	These printed parts act as connectors for the assembly of a wooden table, so some tolerances may be needed when printing them.
Accuracy and definition required. (Quality) Low, mid or High.	Mid or High
Support material or post-processing.	If the angles do not exceed 45° no support material is required. Sanding will be applied as post-processing to remove possible imperfections.

14. Exercise "SHAPES4U".

INFORMATION

Exercise Name	SHAPES4U
Specific Subject	Technical drawing and wood workshop for the disabled people
Number of pieces of which the model is composed	15 pieces

3D MODEL DESCRIPTION

Written description.

The exercise has been designed to facilitate people with cognitive disabilities in the creation of geometric shapes with wood.

This exercise will allow the disabled person to not only be able to draw flat geometric shapes on a piece of wood such as: the triangle, the rectangle, the rhombus, etc., but also more complex ones: circle, ellipse, etc. On the other hand, it will also allow them to carve these shapes in wood. The shapes will allow the disabled person to easily manipulate them and to recognize shapes, perimeters, and areas much more easily than before.
Thanks to the shapes, students with cognitive disabilities can glue the geometric shape onto the piece of wood with double-sided adhesive tape. This can be cut both with normal tools such as the saw but also with the electric or column saw.

All the printed geometric figures will be of 3 different sizes: small, medium, and large.

- Overall: 50x50x70mm
- Overall: 80x80x70mm
- Overall: 150x150x70mm

Graphic Definition of the 3D Model. (Technical draws, hand free sketches and renders).

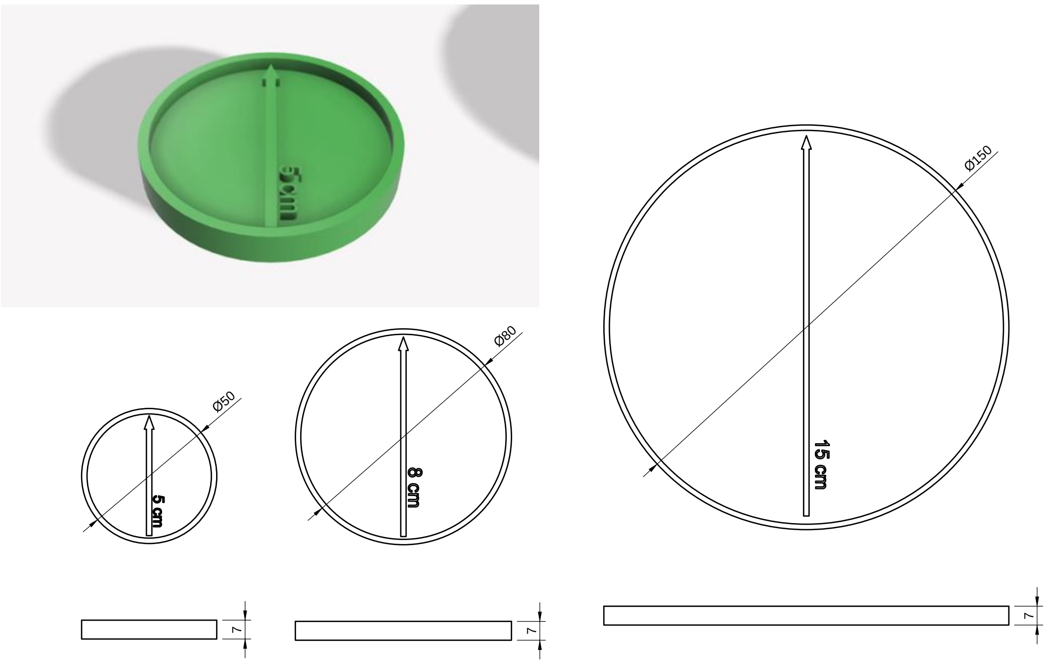


Figure 73: Circle model.

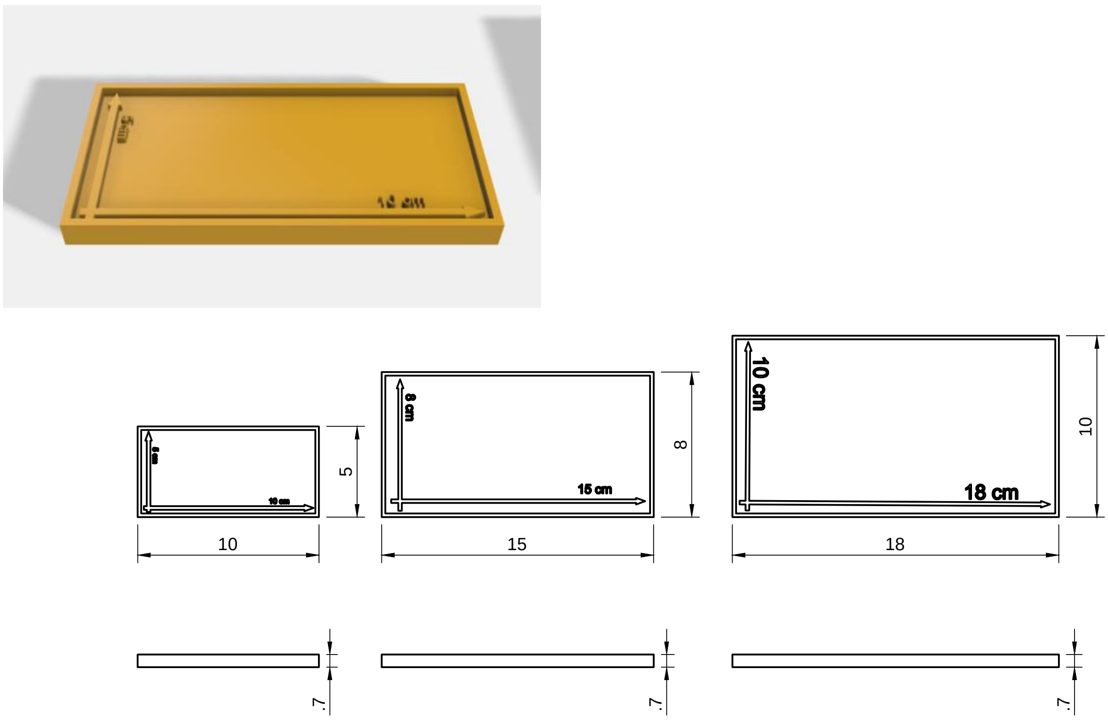


Figure 74: Rectangle model.

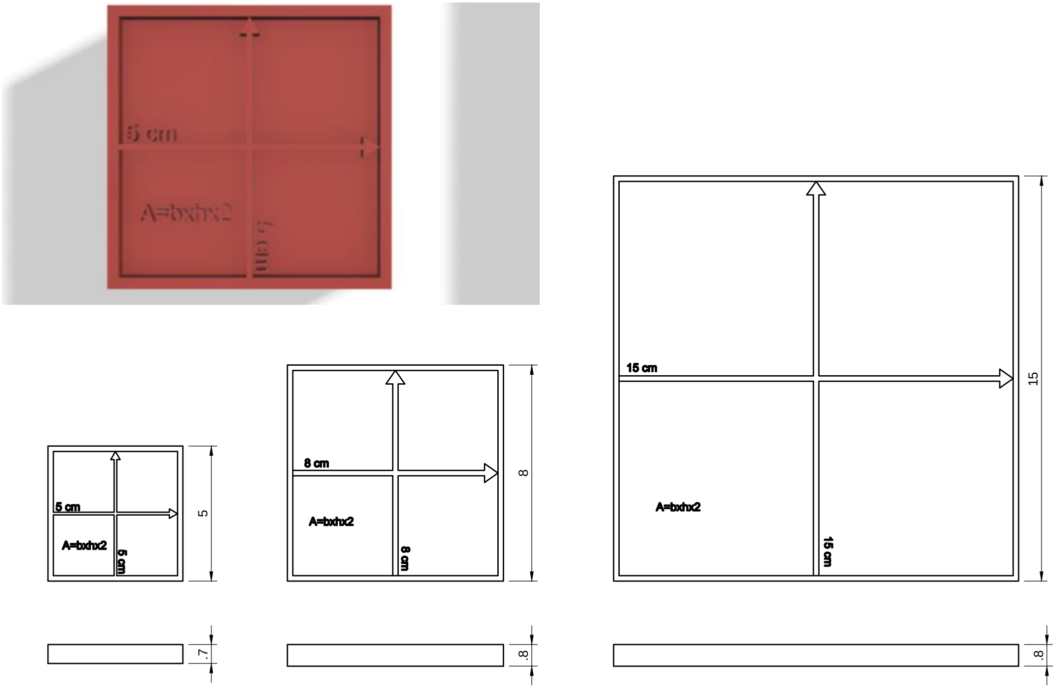


Figure 75: Square model.

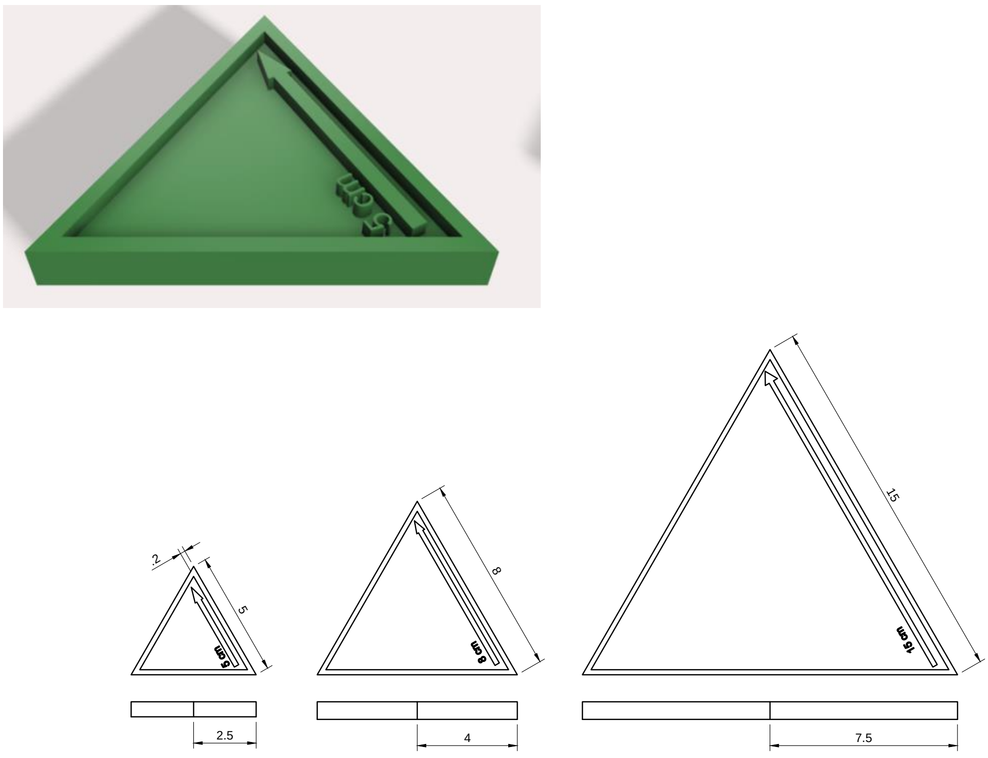


Figure 76: Triangle model.

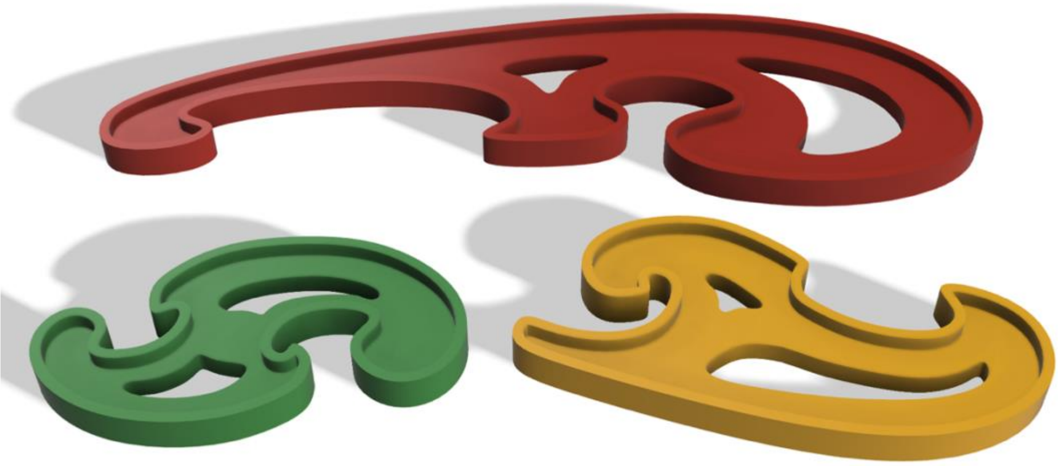


Figure 77: Shapes model.

Additional materials for a better description.

Figure 78: Examples of the use of this exercise.

TEACHING SPECIFICATION

How can this model be used in the classroom?

The exercise will be used during the geometry lesson, technical drawing, but also in the workshops for making wooden objects and furnishings (carpentry). This exercise will help the students to understand the dimensionality of an object at the visual spatial level of what they imagine.
Having a fixed figure for students with cognitive disabilities will help them understand the concept of perimeter, area, side, angle, vertex and so on ...
It will also be useful for improving visual memory, motor memory, dimensionality, and image memory.
Thanks to the various figures, a student with cognitive disabilities will be able to reproduce the same figure in other types of materials. He will be able to make the carvings following the perimeter of the figure itself and reproduce the various figures, from the simplest to the elliptical ones, correctly and easily.

What methodology can be used for its integration into the classroom/curriculum?

All the exercises developed for disabled people must follow two different methodologies. The technical one respecting the piece that is being developed and the one related to the kind of disability.
For the disability one, the methodology that should be applied would be the ABA (Applied Behaviour Analysis) one. ABA is the most used science in the intervention with people who have autism spectrum disorders, cognitive, behavioural, and emotional disabilities.
ABA is based on direct observations of behaviour as a primary measurement tool. The promoted skills must be objectively quantifiable and directly observable: the functional relationships between the individual and the environment are identified, objectively establishing causal relationships between environmental events, and observed behaviours. This process takes place through the systematic manipulation of the environment and the detection of behaviours exhibited under varying environmental conditions.
In ABA, the teaching procedures are described in detail, to facilitate their replication. The ABA procedures refer directly to the principles of behaviourism, excluding the forms of intervention lacking systematicity, or identified by the scientific community as "of reduced effectiveness" or "of not proven effectiveness".

The goal of the ABA is to promote the generalization of skills across different environments, people, and behaviours.

What benefits can be obtained with its use?

Students with the exercise will be able to improve:

- Visual, motor and image memory.
- Pre-syntactic skills (association of a quantity of objects to a number).
- It will help build images mental, static, or dynamic, related to concepts, that allow the
- Re-enactment of the related content. Image memory.
- Pre-syntactic skills (association of a quantity of objects to a number).
- Lexical skills (visual recognition of colours, dimensions and shapes).
- Counting strategies (backward enumeration, ordering from largest to smallest).

It will help build images mental, static, or dynamic, related to concepts from store, that allow the re-enactment of the related content.

TECHNICAL SPECIFICATIONS OF THE EXERCISE

Technology	FDM
Material	PLA
Suitable dimensions for its use in the classroom (mm)	3 different ones: Overall: 50x50x70mm Overall: 80x80x70mm Overall: 150x150x70mm
Should the piece be resistant or be subjected to stress?	No
Number of pieces of which the exercise is composed:	15
Ensemble type if necessary (slot, clip, screwed ...)	No
Accuracy and definition required. (Quality) Low, mid or High.	Low
Support material or post-processing.	No

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