

Lesson Plans

CNC

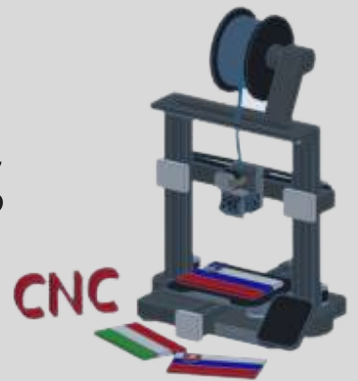
2023-2-SK01-KA210-VET-000184496

01. 01. 2024 -31. 12. 2025



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Programming and coding in vocational education



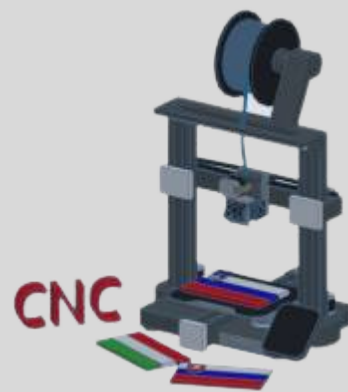
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SPOJENÁ ŠKOLA
Kollárova 17 SEČOVCE



2023-2-SK01-KA210-VET-000184496

CNC

01. 01. 2024 -31. 12. 2025

Lesson plan

Subject: CNC PROGRAMMING

Topic: Manufacturing a simple cylindrical part

Teaching objectives:

Students will become familiar with the basic functions and principles of working on a CNC lathe. They will learn to create basic programs for turning cylindrical parts. They will develop their skills in reading and applying CNC code (G-code).

Materials needed:

·CNC lathe ·Aluminum or plastic blanks ·CNC programming software (e.g. CAM program) ·Laptops or computers with access to the software Protective equipment (goggles, gloves)

Introduction: Brief introduction to the objectives of the lesson – production of a simple cylindrical part on a CNC lathe. Discussion of how turning works and what can be created using a CNC lathe.

Structure of the lesson

Warm-up activity: Presentation of a CNC lathe - demonstration of the main structure of the machine (head, tool head, spindle, clamping mechanism). Discussion of safety rules when working with the machine.

Explanation and introduction of new learning material:

Explaining the basics of CNC programming for turning. Going through the basic G-codes used on a CNC lathe, such as:

G00 (rapid traverse)

G01 (linear motion)

G02/G03 (circular motion) Example of how to enter a basic program to create a cylindrical part (e.g. G-codes to taper an aluminum blank).

Guided or independent work of students:

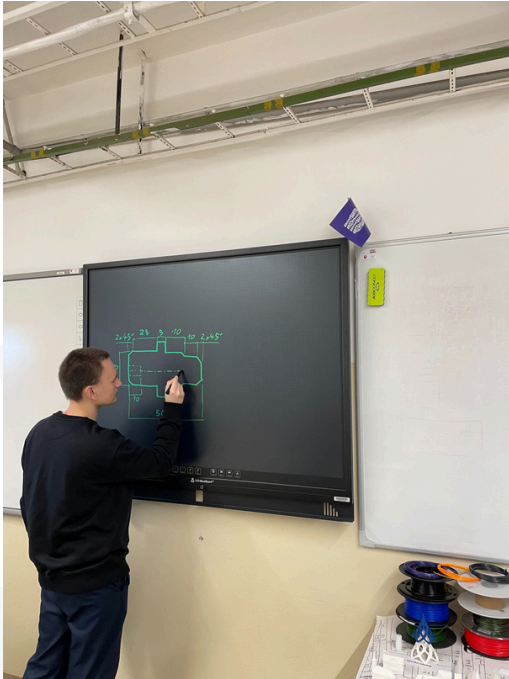
Students in groups are tasked with creating a simple CNC lathe program that will turn a cylindrical part with defined dimensions. Each team can then submit their program and run it on the lathe.

Evaluation and conclusion:

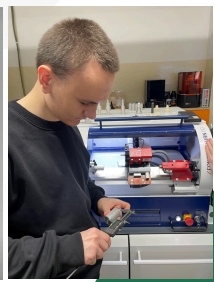
Each group presents the final piece and discusses the problems or challenges they faced. A short evaluation and feedback from the teacher on the quality of the programming and the final product.

Appendix

Photos from the lesson:



Student work and outputs:



Lesson plan

Subject: CNC PROGRAMMING

Topic: Making a chess piece on a CNC lathe

Teaching objectives:
Students will become familiar with the basic functions and principles of working on a CNC lathe. They will learn to create programs for turning specific shapes, such as a chess piece (e.g. a pawn). They will develop the ability to read and apply CNC code (G-code) to more complex parts.

Materials needed:
CNC lathe
Semi-finished products (plastic or aluminum rods)
CNC programming software (e.g. CAM program)
Laptops or computers with access to the software
Protective equipment (goggles, gloves)

Introduction: Introducing the goal of the lesson – creating a chess piece (e.g. a pawn) on a CNC lathe.

Discussion on the use of CNC technology in mechanical engineering and in the creation of complex parts.

Structure of the lesson

Warm-up activity: Presentation of a CNC lathe - demonstration of the main parts of the machine: Head, tool head, spindle, clamping mechanism. Discussion about safety rules when working on a CNC machine. Presentation of a chess piece model and analysis of shape features (cylindrical base, spherical top, and connecting parts).

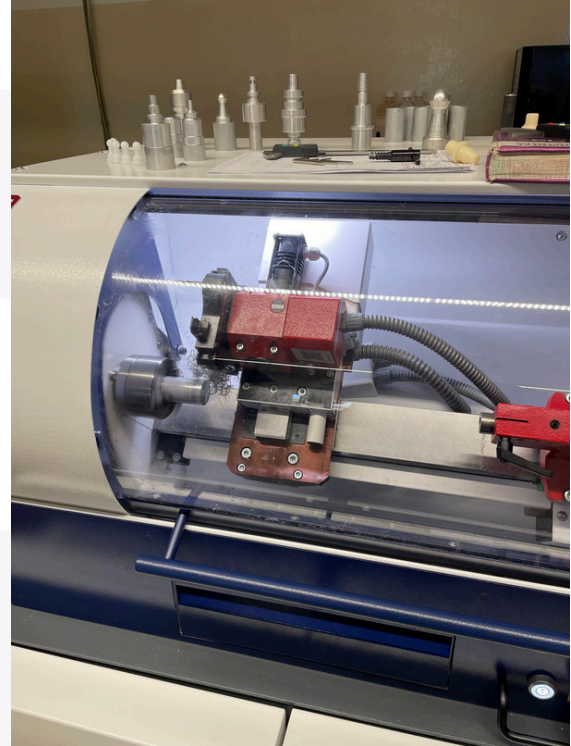
Explanation and introduction of new learning material:
Explanation of the basics of CNC programming, focused on the production of a chess piece - Basic G-codes:
G00 (rapid traverse)
G01 (linear motion)
G02/G03 (circular motion).
Defining the working dimensions of the figure (e.g. height 60 mm, base diameter 30 mm).
Programming example: Creating a figure contour Discussion of the process of turning individual shaped parts.

Guided or independent work of students:
Task: Students work in groups to create a CNC program for turning a chess piece.
Procedure:
Groups will write a program based on a template and consultation with the teacher.
They will test the program on a CNC software simulator.
They run the selected program on a lathe, producing a figure.
Output: Each group completes and hands over one chess piece.

Evaluation and conclusion:
Each group presents its figure:
Comparing the accuracy of the manufactured part with the original. Discussion of challenges during programming (e.g. incorrect dimensions, errors in code).
Feedback from the teacher: Evaluation of the quality of the program and the resulting product. A brief summary of what students learned and what they could improve.

Appendix

Photos from the lesson:



Student work and outputs:



Lesson plan

Subject: CNC PROGRAMMING

Topic: 3D Printing - Design and Printing Personalized Keychains

Teaching objectives:

Students will learn to work with basic 3D modeling software.

They will become familiar with the process of preparing a 3D model for a 3D printer.

They will develop skills in designing and optimizing models for printing.

Materials needed:

3D printer

Filament (PLA or ABS)

Computers with 3D modeling software installed (e.g. ZW 3D, TinkerCAD, Fusion 360)

Protective equipment

Introduction: Introducing the lesson objective – to design and print personalized logos or simple characters using a 3D printer. Brief discussion of the capabilities of 3D printing and how it differs from CNC machining.

Structure of the lesson

Warm-up activity: 3D printer demonstration - explanation of the basic parts (extruder, build plate). Discussion of different filament types and correct printing temperature. Discussion of safety when working with a 3D printer.

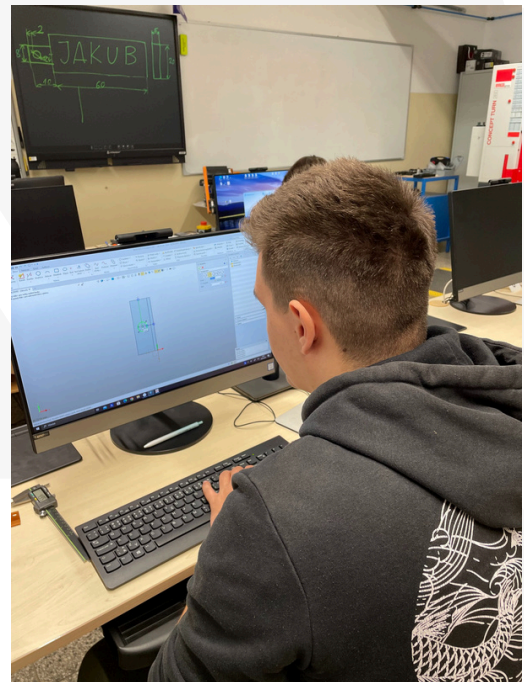
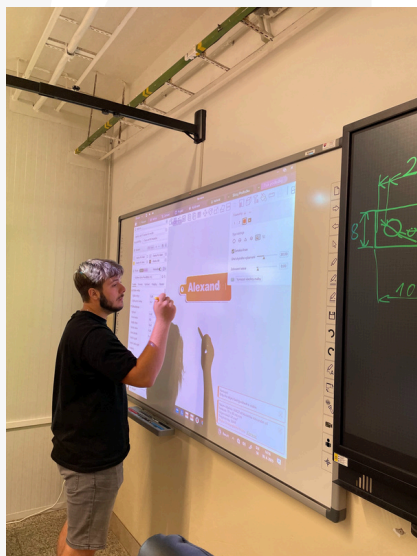
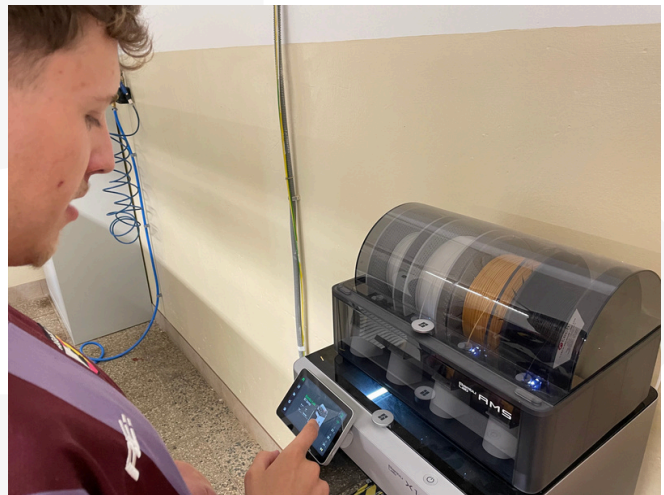
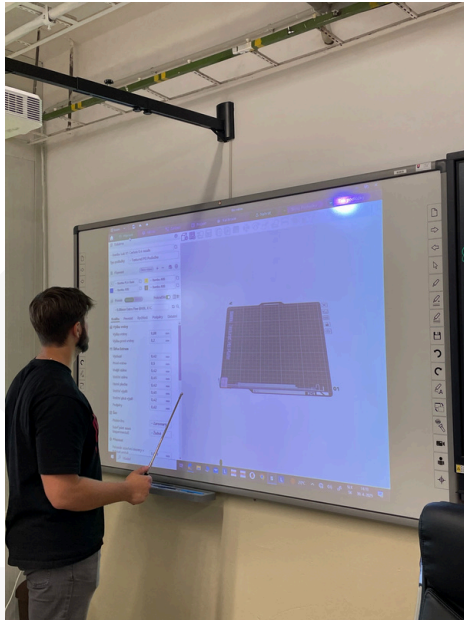
Explanation and introduction of new learning material:
Explanation of the basics of 3D modeling. Presentation of a logo design in TinkerCAD or Fusion 360, ZW3D, subsequent preparation of a file for a 3D printer (STL file). Students will learn to adjust printing parameters (speed, layer thickness) in the slicer.

Guided or independent work of students:
Students design a simple keychain or badge and prepare it for 3D printing. Each team then starts printing their project.

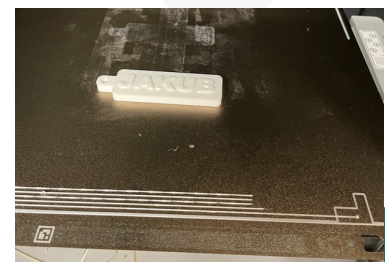
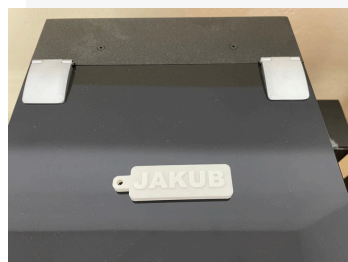
Evaluation and conclusion:
Presentation of printed keychains and discussion of print quality and settings used. Evaluation of results and discussion of design optimization for future projects.

Appendix

Photos from the lesson:



Student work and outputs:



Lesson plan

Subject: CNC PROGRAMMING

Topic: Production of a simple shaped part

Teaching objectives:

Students will become familiar with the basic functions and principles of working on a CNC milling machine.

They will learn to create basic programs for milling simple shapes.

They will learn how to work with G-codes specific to milling and their application in practice.

Materials needed:

CNC frézka

Aluminum or plastic workpieces

ZW3D CNC programming software,

Laptops or computers

Protective equipment (goggles, headphones, gloves)

Introduction: Introduction to CNC milling - explanation of the difference from turning, types of movements and what products can be produced by milling.

Structure of the lesson

Warm-up activity:

Demonstration of a CNC milling machine - explanation of structural parts (X, Y, Z axis, spindle, clamping surface, tools). Discussion about safety - why it is necessary to have eye and hearing protection, correct clamping of the material.

Explanation and introduction of new learning material:

Overview of G-codes used in milling:

G00 - rapid traverse

G01 - linear milling

G02/G03 - circular interpolations

G17/G18/G19 - selection of machining plane

Example of a simple program for milling a rectangular profile with a recess.

Guided or independent work of students:

Students will write a program to mill a simple shape according to the assignment (e.g. a 40x20 mm pocket with a depth of 5 mm).

Simulation in CAM software or actual program execution on a CNC machine.

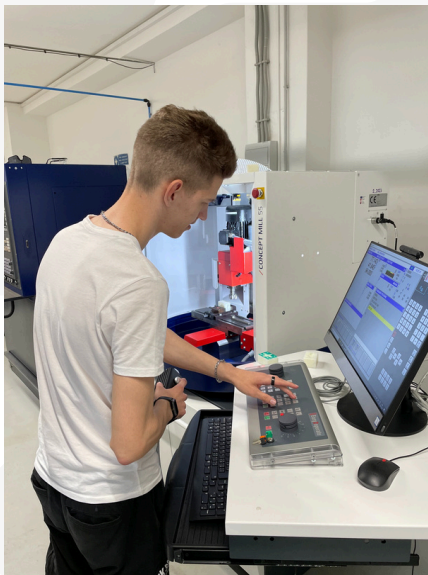
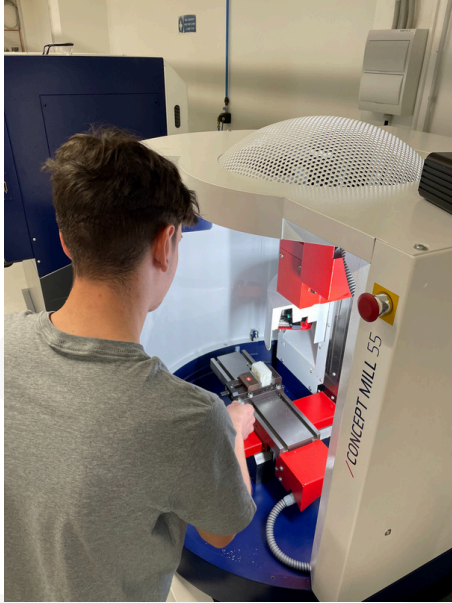
Evaluation and conclusion:

Discussion about milling accuracy, programming errors, evaluation of results.

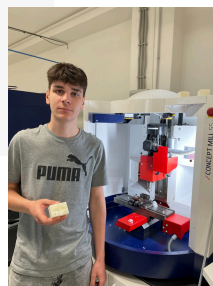
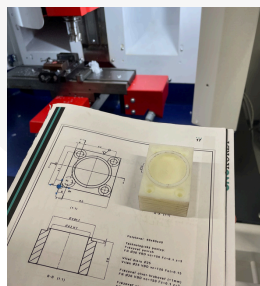
Each team will present how they went about solving the task. The teacher will provide feedback.

Appendix

Photos from the lesson:



Student work and outputs:



Lesson plan

Subject: CNC PROGRAMMING

Topic: Engraving text into POM material

Teaching objectives:

Students will learn how to engrave text into POM material using a CNC milling machine.

**They will gain practical experience in setting parameters for fine milling.
They will master the creation and simulation of text paths in CAM software.**

Materials needed:

CNC milling machine with a suitable engraving cutter (e.g. V-bit, engraving tip)

Plastic sheets (e.g. Plexiglas, PVC, ABS)

CAM software with text generation functionality (e.g. Fusion 360, ZW 3D, Carbide Create)

Computers or laptops

Protective equipment (goggles, headphones)

Introduction: Welcome, introduction to the goal of the lesson – to learn how to engrave your own text into a plastic workpiece.

Discussion: Where is engraving used in practice? (name tags, labels, gift items, logos...)

Structure of the lesson

**Warm-up activity: Demonstration of several engraved products - analysis of what affects quality (tool type, depth, speed).
Discussion of suitable materials for engraving and safety principles when working with a milling machine.**

Explanation and introduction of new learning material:

A demonstration of how to create an engraving trajectory from text in CAM software.

Choose the font, size and placement of the text.

Setting milling parameters (depth, feed, speed).

G-code generation and simulation.

Guided or independent work of students:

Each student or team designs their own text - e.g. name, class, short slogan (up to approx. 20 characters).

They create a milling path in CAM software and export the G-code.

The text is then engraved into the plastic workpiece using a CNC milling machine.

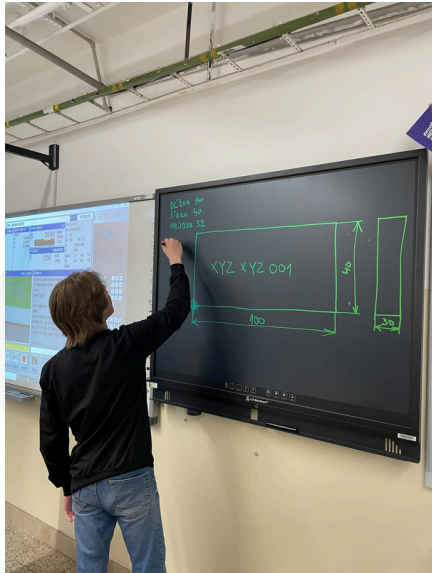
The teacher supervises safety, proper clamping of the material, and selection of tools.

Evaluation and conclusion: Students present their engraved creations. Discussion: What they succeeded in, what they would do differently next time.

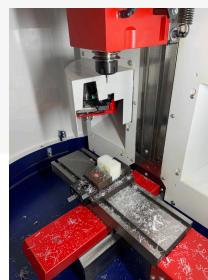
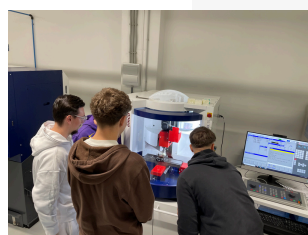
Evaluation of the accuracy, legibility and aesthetic quality of the engraving. Feedback from the teacher and suggestions for further projects (e.g. logos, own designs).

Appendix

Photos from the lesson:



Student work and outputs:



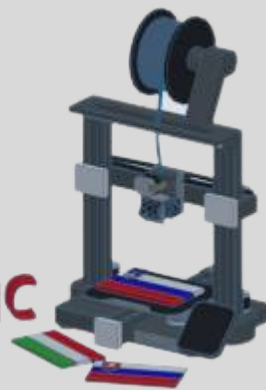


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CNC



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CNC

01. 01. 2024 -31. 12. 2025

Lesson Plan 1

Case:
CNC technology

Learning objectives:
Understanding the role of CAD-CAM technology in modern manufacturing.
Learn to design the basic parts of a birdhouse in AutoCAD.
Generation of NC code in TPA CAD and simulation of execution on a CNC machine.

He/She:
Planning and CAD-CAM preparation of NC code for manufacturing a birdhouse on

a CNC machine.
Accessories:
Computers with installed programs: AutoCAD, TPA CAD, 3D Simulator.
Prepared worksheets with dimensions for a birdhouse.
CNC machine for practical work.

Presentation:
Presentation of the importance of CAD-CAM technologies in simplifying product design and manufacturing. Explanation of the workflow: from drawing in AutoCAD to generating NC code for CNC machining.

Lesson structure

Introductory activity (5 minutes):

Discussion about students' prior knowledge of CNC machining and technical drawing. Example questions:

What do you know about CAD software?

How can CNC technology improve production?

Explanation and presentation (10 minutes):

Demonstration of basic AutoCAD functions (e.g. line, circle, trim) and drawing parts of a birdhouse.

Explanation of the process of saving to .dxf format and opening in TPA CAD.

Emphasis on setting processing parameters (speed, depth of cut).

Guided and independent part (25 minutes):

Guided part: Students draw basic parts in AutoCAD under guidance.

Independent work: Students generate NC code in TPA CAD and simulate the process in the 3D Simulator.

Evaluation and conclusion (5 minutes):

Review of NC code created by students and discussion of the most common errors.

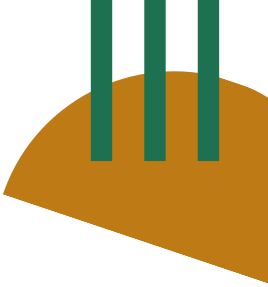
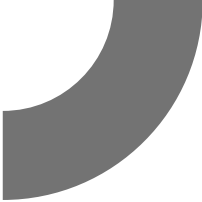
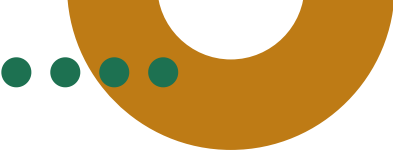
Evaluation of drawings and discussion of possible design improvements.

Reflection on the learning process and answers to any questions.

- **Student products:**

Drawings of birdhouse parts.

Generated NC code and simulation results.



Worksheet

1. Introductory questions

- 1.1. What does the abbreviation CAD mean and what is it used for?
- 1.2. What does CAM mean and how does it interact with CAD?
- 1.3. List at least two examples of how CNC technology improves production:

2. Cannon in AutoCad:

- 2.1. Describe the process of drawing the basic piece of a birdhouse in AutoCAD:
- 2.2. What basic functions did you use?

3. Transfer to TPA CAD

- 3.1. In what format do you save an AutoCAD file for further processing?
- 3.2. What do you need to set up in TPA CAD before generating NC code?
- 3.3. How do you check if the program will perform the processing correctly?

4. Practical task:

Draw parts, export as .dxf, generate NC code

5. Reflection:

What did you learn? What was the hardest thing for you?



Annex

Photos of the lesson:



Lesson plan 2

Case:

CNC technology

He/She:

Making a birdhouse on a CNC machine using CAD-CAM technology.

Learning objectives:

Understanding the process of transferring NC code to a CNC machine and setting up the machine for processing.

Mastering tool settings and vacuum grippers for safe processing.

Assembling a birdhouse from machined parts.

Accessories:

Felder H350 CNC machine with the Albatros package installed.
A computer with TPA CAD, CNC board and Tecno Manager programs installed.

Prepared wooden parts for the birdhouse.

Assembly tools (hammer, pliers, screwdriver).

Introduction:

Explaining the importance of precision in setting up a CNC machine.
Presentation of the steps: loading the NC code, checking the tools and vacuum grippers, machining on the machine and assembling the birdhouse.

Lesson structure

Introductory activity:

Discussion about the machining process on a CNC machine. Example questions:

Why is it important to check tool settings before machining?

How can incorrect adjustment of vacuum grippers affect processing?

Explanation and presentation of the tools (10 minutes):

Demonstration of transferring NC code from a computer to a CNC machine using the TPA Cad program.

Explanation of tool settings and vacuum grippers.

Explanation of the CNC machine startup process and monitoring of processing.

Guided and independent part (30 minutes):

Guided part: 10 minutes - Students, with the help of the teacher, download the NC code and check the settings.

Independent work: 20 minutes - Students operate a CNC machine and make the components of a birdhouse.

Evaluation and conclusion (10 minutes):

Inspection of machined parts and discussion of any machining problems.

Assembling a birdhouse from machined parts.

Summary and reflection on the production process.

Worksheet

1. Introductory questions

1.1. What is NC code and what role does it play in working with a CNC machine?

1.2. Why is it important to check the settings of tools and vacuum grippers before starting processing?

1.3. Describe the steps for transferring NC code from a computer to a CNC machine (TPA CAD).

2. Observation of the process - mark the correct answer

2.1. What does a vacuum gripper enable in woodworking?

☒ Better edge cutting ☒ Material clamping without mechanical force ☐ Automatic cutting

2.2. If the tool is incorrectly adjusted, the following may occur:

☒ Smoother edges ☒ Incorrect cutting depths or material damage ☒ Faster machining

2.3. In which program do we prepare a birdhouse model for CNC machining?

☒ Tecno Manager ☒ TPA CAD ☒ CNC Board

Annex

Photos of the watch:



Student products:

Fully machined birdhouse parts.
Assembled birdhouse.

Lesson plan 3

Case:

CNC technology

He/She:

Handwriting a CNC program for processing a haberdashery board.

LUNA goals:

Understanding the basics of G-codes and M-codes in manual CNC machine programming.
Acquiring skills in planning tool paths using a coordinate system.
Writing a simple CNC program for milling and blanking.

Accessories:

Computers with basic text editors (e.g. Notepad).
Felder H350 CNC machine.
Haberdashery board (width 200 mm, length 450 mm and thickness 20 mm).

Introduction:

Explanation of the importance of manual programming as a basis for understanding automated systems. Presentation of basic G- and M-codes and comparison with TPA software.

Lesson structure

Introductory activity (5 minutes):

Discussion on the basics of the coordinate system and toolpath coding.

Example questions:

Why is the coordinate system important in CNC programming?

How are tool movements determined in an NC program?

Explanation and presentation of the handouts (10 minutes):

Understanding the basics of the coordinate system in CNC programming.

Understanding the importance of accurate tool path planning.

Skills:

Writing a CNC program step by step.

Using milling parameters (depth, milling speed, offsets).

Guided and independent part (25 minutes):

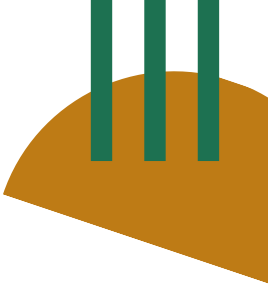
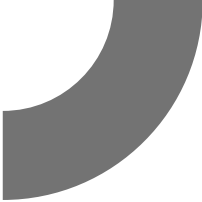
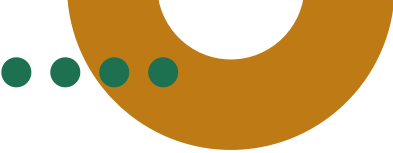
Guided part: Students write a basic CNC program for rough and fine trimming under the guidance of a teacher.

Independent work: Students add commands for emptying the middle and check the program on a simulator (if available).

Evaluation and conclusion (5 minutes):

Review of written programs and discussion of possible errors.

Summary of key points and answers to questions.



Worksheet

1. Answer the questions

1.1. What does the abbreviation CNC mean and what does such a machine enable?

1.2. Why is knowing the coordinate system important in CNC programming?

1.3. Describe the difference between G-code and M-code.

2. Fill in the blanks

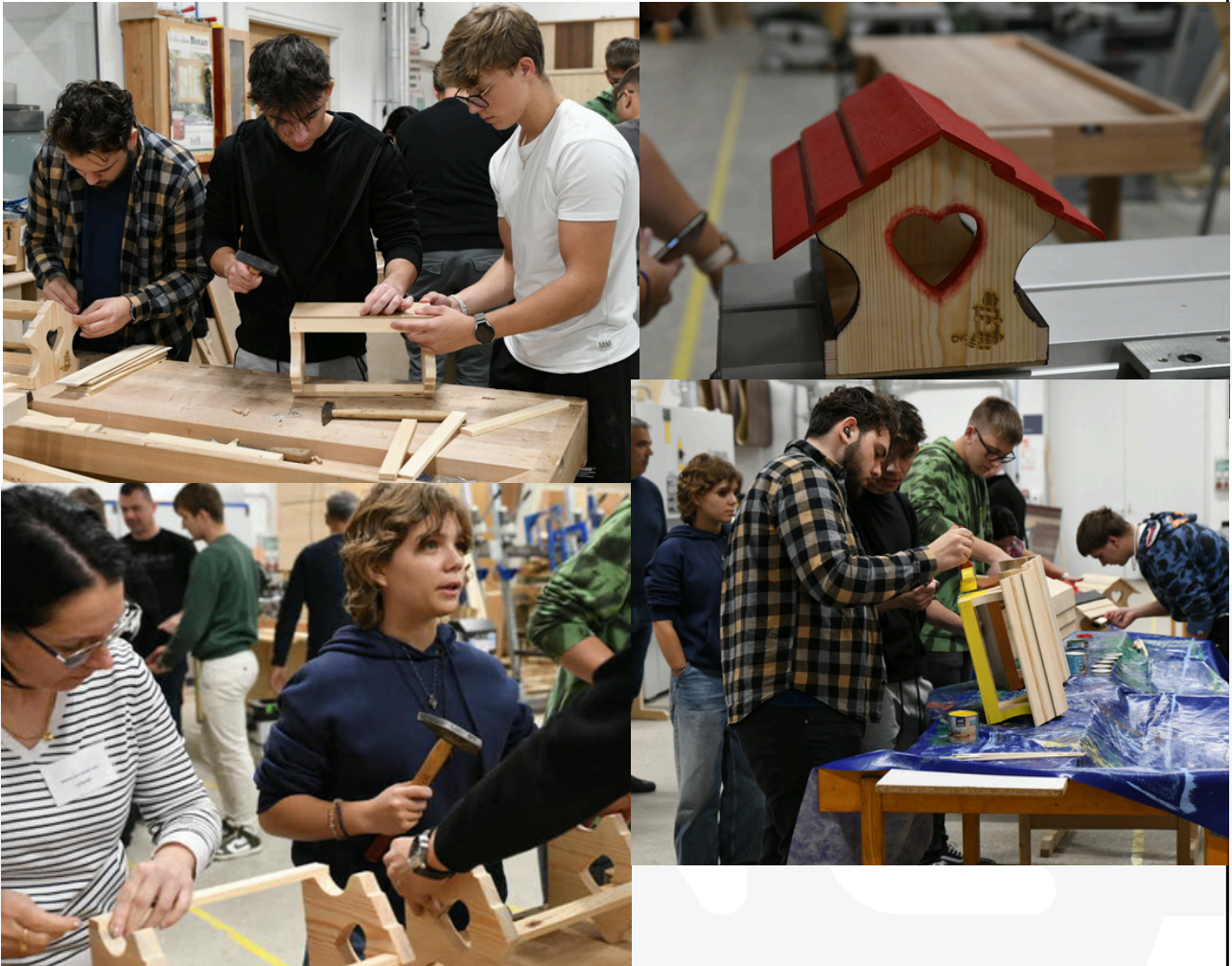
Complete the sentences with the correct expression:

(G-code, M-code, X, Y, Z, Notepad, depth, displacement, Felder H350)

- a) The CNC machine we use in the exercises is called _____.
 - b) The tool in the CNC program moves along three axes: _____, _____ and _____.
 - c) The code for tool movements is written with _____.
 - d) Commands for machine functions, such as turning on the spindle, are specified with _____.
 - e) A simple CNC program can be written in the _____ editor.
 - f) When milling, we must also determine the _____ of milling.
- 
- 

Annex

Photos of the watch:



Student products:

Written CNC programs.
Treated haberdashery board.

Lesson plan 4

Case: CNC technology	He/She: CNC technology – Designing and drawing beehive components in AutoCAD
Learning objectives: • Develop an understanding of the functions of CAD tools for technical drawing of wooden structures. • Draw the parts of a beehive using basic tools in AutoCAD. • Correctly determine dimensions, tolerances and markings of components.	Materials and tools: • Computers with AutoCAD, TPA CAD, CNC Simulator. • CNC machine. • Prepared wood (according to dimensions for the parts of the stump). • Assembly tools (screwdriver, staples, etc.).
Clock structure: 1. Introduction (5 min) – discussion about the role of CAD in modern beekeeping and woodworking. 2. Explanation (10 min) – demonstration of basic functions (line, circle, dimensioning, layers). 3. Guided exercise (15 min) – joint drawing of one basic part (e.g. entrance panel with vent). 4. Independent exercise (15 min) – students draw additional parts (e.g. back wall or interior partitions). 5. Evaluation (5 min) – review of drawings and discussion of accuracy.	

Lesson structure

1. Introductory activity (5 minutes):

Discussion with students about prior knowledge:

- What do you know about drawing in AutoCAD?
- How would you imagine designing the components of a hive?
- What elements are important in a technical drawing (dimensions, layers, scale)?

The goal of the introduction: to activate prior knowledge and connect the content with real-world application (beekeeping, CNC machining).

2. Explanation of new learning material (10 minutes):

Classroom demonstration with computer and projector:

1. Using basic commands in AutoCAD (e.g. Line, Trim, Offset, Layers).
2. Planning one part of the hive (e.g. entrance panel).
3. Correct use of layers and dimensioning.
4. Save the drawing in .dxf format.

The teacher continuously explains the importance of technical requirements and precision in preparation for CNC machining.

3. Water exercise (15 minutes):

Students under the guidance of a teacher:

- They open AutoCAD and create a new drawing.
- Using instructions, they draw a specific part of the tree stump (e.g. the front or back side).
- They use tools such as: Polyline, Trim, Mirror, Dimension, Layer Properties.

The teacher walks among the students, gives advice and points out common mistakes

4. Independent exercise (15 minutes):

- Students independently draw the second part of the hive (e.g., the inner partition or ventilation panel).
- Finally, they save the drawing in .dxf format.
- They submit a screenshot as proof of work done.

Lesson structure

5. Student products

1. Digital technical drawing (.dwg or .dxf file) Each student creates a technical drawing of one or more components of a beehive, for example:

- entrance panel with vent
- side or back wall
- internal partition or honeycomb frame

The drawing includes:

- exact dimensions (according to instructions)
- using different layers (contours, dimensions, inscriptions)
- appropriate line types and thicknesses
- basic dimensioning and drawing naming (if provided)

2. Screenshot or preview of the drawing

- Students create a screenshot or PDF preview of the final drawing.
- The recording can be pasted onto a worksheet or submitted digitally.

3. .dxf file for further processing

- Students export their AutoCAD drawing in .dxf format.
- The file is ready for use in TPA CAD or for further CNC processing.
- The naming is consistent (e.g. Name_Panj_dan_1.dxf).

4. Completed worksheet

- Answer questions about the workflow.
- Personal reflection (what went well, what could be improved).
- Any drafts/sketches or conceptual notes.

5. (If necessary) Short self-assessment or drawing quality check

- Control: dimensions, use of tools, order of layers
- Complement: "What would you do differently next time?"

Worksheet

1. Drawing Basics

1.1. What tools did you use to draw today? (circle)

☐ Line ☐ Circle ☐ Trim ☐ Dimension ☐ Copy ☐ Mirror ☐ Arrange

1.3. Describe one of the parts of the beehive that you drew:

Part name: _____ Function of this part in the hive:

2. Cannon in AutoCAD

2.1. How did you determine the dimensions for the drawing?

2.2. In which layers did you draw the individual elements? Why is this important?

2.3. Add a screenshot or hand-drawn sketch of the piece:

Annex

Photos of the watch:



Lesson 5

Case: CNC technology	He/She: CNC technology – Preparation and production of beehive components on a CNC machine
Learning objectives: • Connect CAD design with manufacturing in a CAM environment (TPA CAD). • Correctly export .dxf files and prepare NC code. • Operate a CNC machine to manufacture beehive components. • Assemble the basic hive units using the prepared pieces. •	Materials and tools: • Computers with AutoCAD installed. • Floor plans or sketches of the components of the hive. • Photos for orientation. • Drawing planning worksheet.
Clock structure: 1. Introduction (5 min) – the importance of precision and safety in hive construction. 2. Explanation (10 min) – demonstration of .dxf export, parameter setting in the CAM environment, simulation. 3. Guided exercise (15 min) – NC code transfer, tool and gripper check. 4. Independent implementation (15–20 min) – processing part of the hive, assembling. 5. Evaluation (5 min) – reflection, product photography, discussion of potential problems.	

Lesson structure

1. Introductory activity (5 minutes):

Discussion about safety and preparation for CNC machining:

- Why is accuracy important when transferring files?
- What can happen if the cutting depth is set incorrectly?
- How does a vacuum gripper work?

Emphasis on the real problem: if the drawing is bad → the processing will be wrong.

2. Explanation of the procedure (10 minutes):

The teacher presents on a projector or CNC terminal:

1. Export CAD drawings in .dxf format.
2. Import into TPA CAD, defining tool paths.
3. Settings: cutting depth, speed, tool, material.
4. Processing simulation in a 3D simulator.

If possible, the teacher shows an example of an error in the simulation and how to fix it.

3. Water exercise (10 minutes):

Students together with the teacher:

- They transfer the NC code to the CNC machine.
- They check the tools, heights, starting points.
- They set up the grippers and prepare the material.

Emphasis on safe handling and correct machine setup.

4. Individual performance (15–20 minutes):

Each student (or in pairs):

- Starts processing of a single part of the hive.
- Monitors the process and stops the machine if necessary.
- Inspects product quality (dimensions, edges, suitability).

Next comes the assembly of the basic hive element (if there is time).

5. Evaluation and reflection (5 minutes):

Students analyze together:

- Which part of the processing was the most challenging?
- What could be improved when preparing NC code?
- How important is the connection between CAD and CAM?

Submitting the worksheet + taking photos of the finished product (if possible).

Lesson structure

6. Student products

1. Correctly exported NC code (from TPA CAD) Students create NC code from AutoCAD drawings in the TPA CAD program.

The file is saved in the appropriate format and with the appropriate name (e.g. Panjska_stranica.nc).

The NC code must contain:

- correctly defined tool path
- set cutting depth, speed and starting points
- any markings for tool change or stop function

2. Processing simulation (if 3D simulator is available)

- Students run a machining simulation in a TPA environment or another CNC simulator.
- They check the correctness of the tool path, any collisions or deviations.

Result: screenshot of the simulation or certificate of successful simulation.

3. A manufactured component of a beehive on a CNC machine. Students actually machine one piece of the hive (e.g., a wall, an entrance panel, a lid, or a partition).

The result must have:

correct dimensions and smooth edges, properly attached points (if provided), no visible damage or defects

Students can take photos of the finished product as evidence.

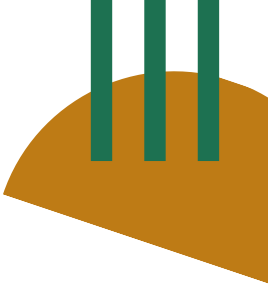
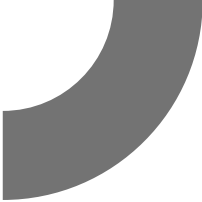
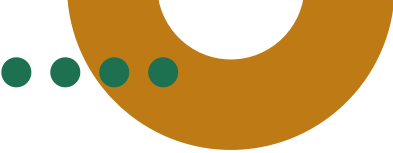
4. (Optional) Assembling the Basic Hive Assembly If time and materials allow, students assemble several fabricated pieces into a basic structure (e.g., hive body).

They use hand tools (screwdriver, staples, glue).

A photo or product view can be part of the presentation.

5. Completed worksheet with technical observations and reflection

- Entering data about:
 - files (.dxf and .nc)
 - settings used in the CAM program
 - machine observations (noise, speed, material behavior)
- Reflection:
 - What did they achieve?
 - Where did they have problems and how did they solve them?
 - What would you do differently?



Worksheet

1. Preparation for processing

- 1.1. What format do you use to export your drawing?
- 1.2. What do you set in TPA CAD?
- 1.3. What do you check before starting the machine?

2. Implementation and observation

- 2.1. What did you make?
- 2.2. How did the procedure go?
- 2.3. What problems did you notice?

3. Assembly and inspection

Check the quality: edges, dimensions, functionality. Does the product work? Do the parts match?

4. Reflection

What did you learn? What would you improve next time?

◦

Annex

Photos of the watch:

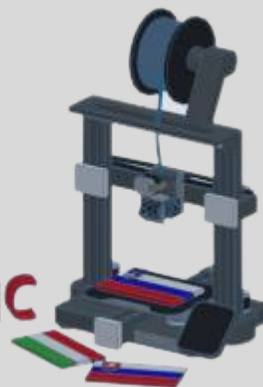




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CNC

01. 01. 2024 -31. 12. 2025

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Lesson plan

Subject:

CNC technology

Topic:

Coaster design and CNC machining (with simulation) - 1st lesson

Learning objectives:

- Students will learn the basic functions of AutoCAD.
- Students will learn to design coasters in AutoCAD.

Required materials:

- Computers with AutoCAD software installed
- Projector/interactive whiteboard
- Coaster patterns (optional)

The structure of the lesson

Introduction (5 minutes):

- A brief introduction to the concept and process of CNC machining
- Introducing the coaster as a project

CNC machining: A manufacturing process that uses computer-controlled machine tools to precisely remove material from a workpiece to create unique parts or products.

Steps of the CNC machining process:

CAD design (result: blueprint), CAM programming (result: G-code), CNC machine setup (fixing workpiece, selecting tools, loading G-code), Machining.

Transfer of new knowledge - AutoCAD basics (15 minutes):

- Introduction to the AutoCAD user interface. (3 minutes)
 1. Introduction to ribbons and panels.
 2. Introducing zoom: students will learn how to zoom with the mouse wheel.
 3. Pan, i.e. shifting the view within the drawing: students will learn about the “pan” function, which is achieved by pressing and dragging the middle mouse button.
- Introduction and practice of basic drawing elements and commands. (9 minutes)
 4. Students will learn about the drawing elements of lines, polylines, circles, rectangles, and arcs.
 5. Students will learn about the tools for moving, rotating, deleting, copying, mirroring, rounding, stretching, scaling, and shifting.
- Adding texts. (2 minutes)
- Save the drawing as a DWG and then DXF file. (1 minute)

Guided and then independent practice - Designing a coaster (20 minutes):

Showing examples of different coaster shapes and designs.

1. Guided part: Students create a drawing of the coasters presented as samples in AutoCAD under guidance. (10 minutes)

The patterns progress from simple to more complex.

Example 1: square coaster with rounded corners

Example 2: circular recessed coaster

Example 3: square coaster with rounded corners and a circular indentation

2. Independent part: Students independently design their own coasters in AutoCAD. (10 minutes) The teacher provides assistance with any questions that arise.

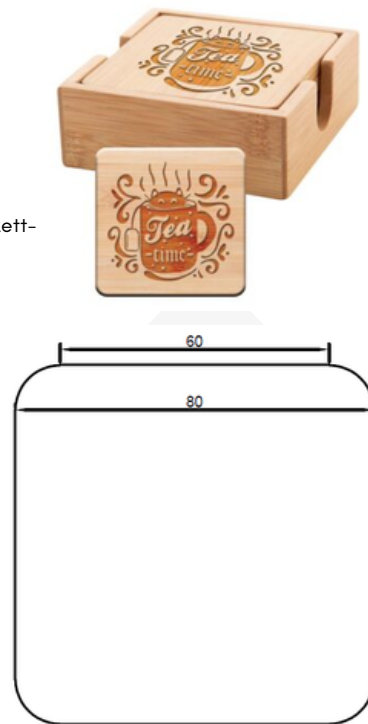
Example 1: square coaster with rounded corners

Image source: <https://www.csepeligravir.hu/termek/bambusz-poharalatt-szett-tartoban-tea>

Students will receive the following scaled blueprint printed out and then prepare it in AutoCad.

Tools needed to create the drawing:
Draw/Rectangle, Modify/Round.

Students calculate the radius of the rounding (10) based on the drawing.



Example 2: circular recessed coaster

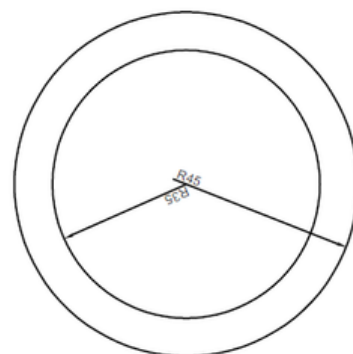
Image source:

<https://www.joom.com/hu/products/62b590fcedc07301fab8239b>

Students will receive the following scaled blueprint printed out and then prepare it in AutoCad.

Tools needed to create the drawing:
Draw/Circle, Modify/Offset.

Use the Offset tool to create a circle concentric with the first circle drawn. The students calculate the amount of displacement (10) based on the drawing.



Example 3: square coaster with rounded corners and a circular indentation

Image source:

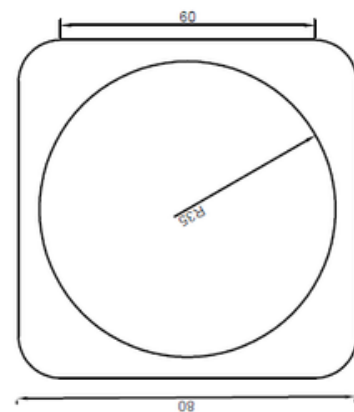
<https://www.joom.com/hu/products/62b590fcedc07301fab8239b>



Students will receive the following scaled blueprint printed out and then prepare it in AutoCad.

The tools needed to create the drawing are: Draw/Rectangle, Draw/Circle, Modify/Round, Modify/Offset, Modify/Delete.

Tip: Draw guide lines parallel to the sides of the square at a distance of 40 units, and their intersection will be the center of the circle. Finally, delete the guide lines.



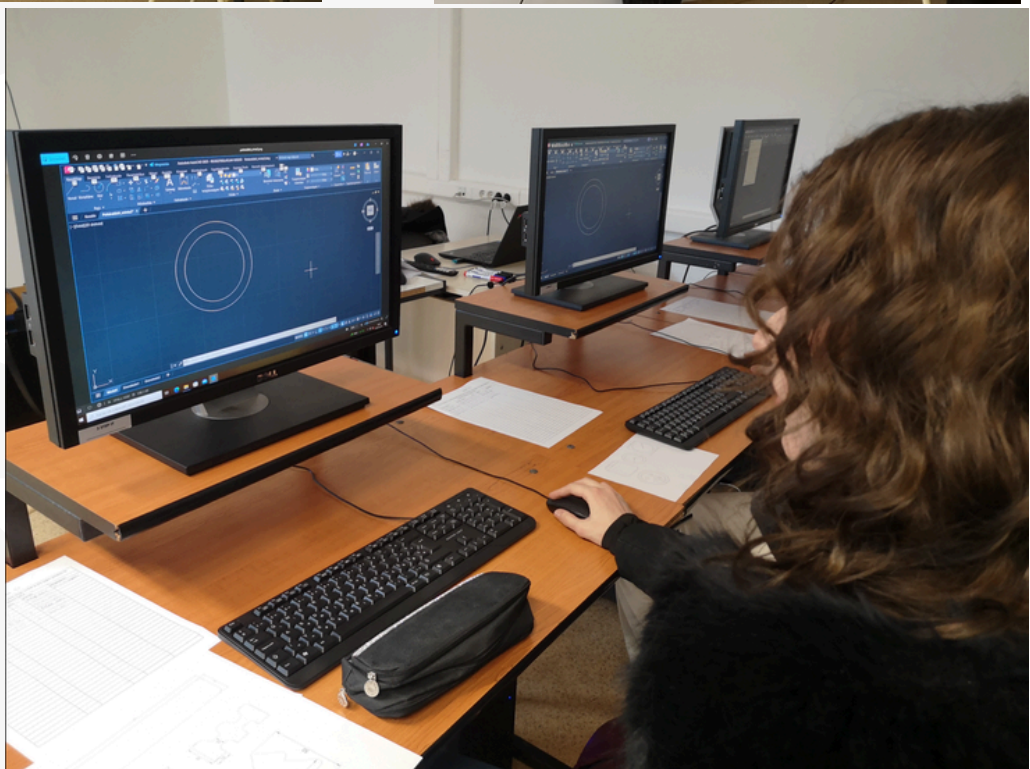
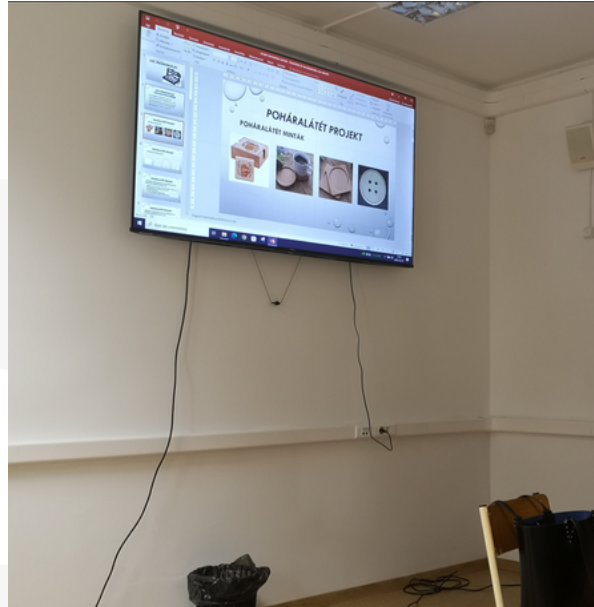
Evaluation and closing (5 minutes):

- Reviewing the drawings made by the students and discussing any errors that may have occurred.
- Evaluating drawings and discussing possible design improvements.
- Reflection on the learning process and answers to possible questions.

Appendix

Photos of the implementation of the watch:

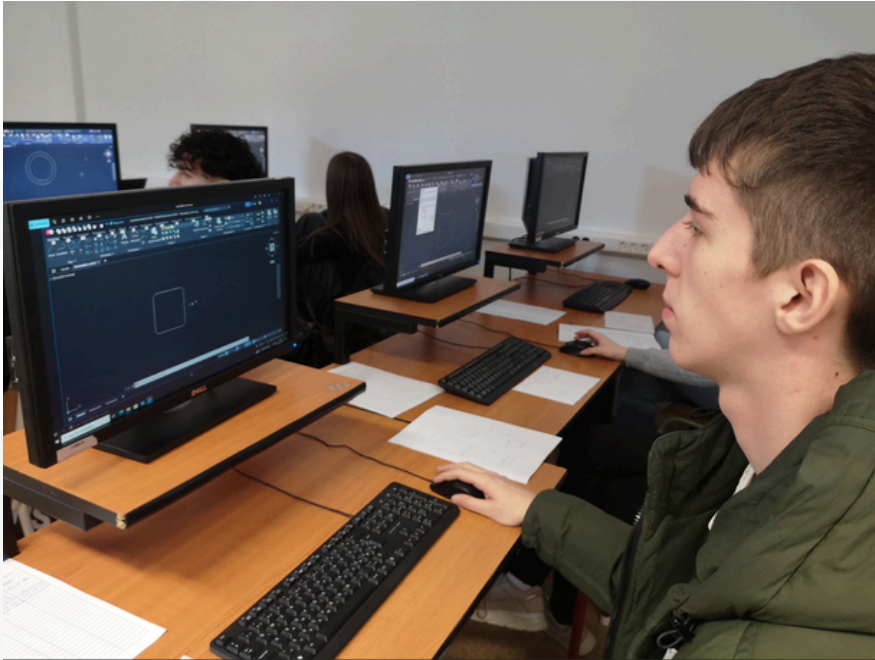
- Pictures of students working in AutoCAD



Appendix

Photos of the implementation of the watch:

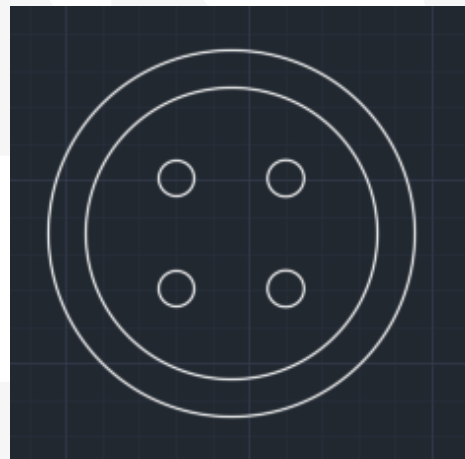
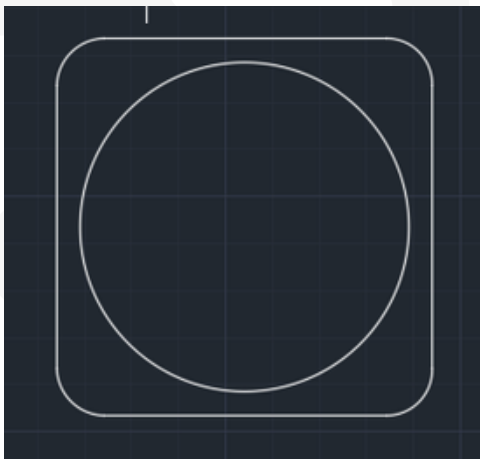
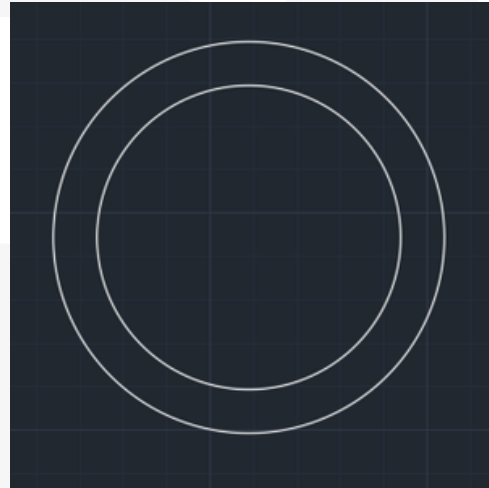
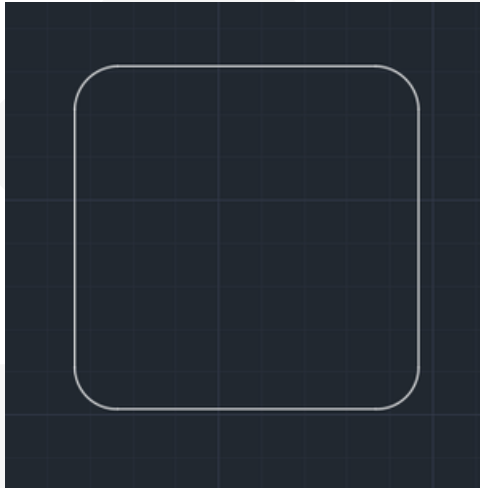
- Pictures of students working in AutoCAD



Appendix

Student output:

- Coaster designs



Lesson plan

Subject:

CNC technology

Topic:

Coaster design and CNC machining (with simulation) - 2nd lesson

Learning objectives:

- Students will learn about the benefits, types, and principles of CNC machining.
- Students learn to generate NC code from the designed drawing.
- Students learn to create a 3D simulation of the CNC machining process.

Required materials:

- Computers with NC code generation software, 3D simulator (e.g. FREECAD, which can be used to create NC code and basic also suitable for level simulation)
- Projector/interactive whiteboard
- Coaster made in lesson 1 - blueprints in .dxf format

The structure of the lesson

Introduction (5 minutes):

- Brief review of the previous lesson's material
- Overview of the CNC machining process

Transfer of new knowledge - Advantages, types, and principles of CNC machining (10 minutes):

The processing of new material is frontal. The teacher involves students in the gathering of knowledge by asking questions.

- **Explaining the benefits of CNC machining**

1. High accuracy and precision (due to the precise movement of the machine, the shape of the product exactly matches the design).
2. Repeatability (the machine is able to repeat the same operation many times, which is the basis of mass production).
3. Flexibility in material selection (suitable for machining metal, plastic, wood, composites)
4. Automation (reduced need for manual labor, increased production efficiency)
5. Creating complex shapes

- **Introduction to the types of CNC machining**

1. Milling: material is removed from the workpiece using a rotating tool
2. Turning: the workpiece rotates while the tool moves linearly and removes material
3. Drilling: making a hole in the workpiece with a drill.
4. Grinding: refining the surface of the workpiece with a grinder.

- **Introduction to the basic principles of CNC machining**

1. The processing of the previous process should not affect the positioning and fixation of the next process.
2. First the inner cavity must be worked out, then the outer shape.
3. The machining process with the same installation or tool should be carried out continuously to reduce errors due to relocation and tool changes.
4. For the same installation, the operation that has the least impact on the stiffness of the material should be performed first.

Guided exercise - NC code creation, 3D simulation (25 minutes):

- Load the .dxf file into the selected CAD-CAM software.
- Overview of the workspaces of the selected CAD-CAM software and the functions of each workspace.
- Create 3D model, Create Jobs, Define Tools, Generate Toolpaths, Export NC code, 3D simulation

Notes:

- The teacher demonstrates the above to the students by creating the NC code for the rounded-corner square coaster (Example 1) made in the previous lesson (Lesson 1).
- The teacher works on the teacher's computer, and the students work on their own computers, following the teacher's instructions and listening to his or her explanations.
- The implementation can be done with the free downloadable FREECAD software, which is suitable for generating the CN code based on a 3D model and also for demonstrating basic CNC workflow simulation.

Creating the NC code for a square coaster with rounded corners (example 1) with FREECAD:

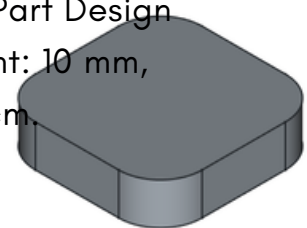
Step 1: Import the .dxf file containing the design into FREECAD.

File/Import or File/Open/Import-Export/DXF/Apply To continue working, turn it on:

View/Panels/Model and View/Panels/Tasks

Step 2: Create a 3D model from the 2D design.

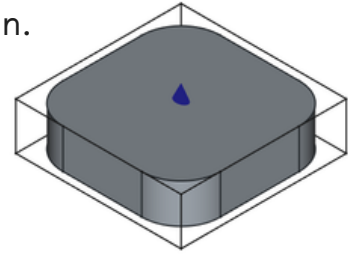
On the Part workspace with the Extrude tool or on the Part Design workspace with the Pad tool. Extrusion (blocking) amount: 10 mm, meaning the material thickness of the coaster will be 1 cm.



Step 3: Create a Job

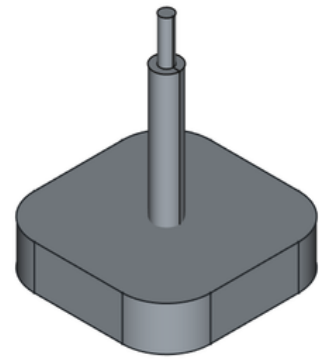
In the CAM workspace, click the Create Job icon. The Model is selected during the Task creation process.

It is also recommended to set the coordinate system.



Step 4: Create a Tool

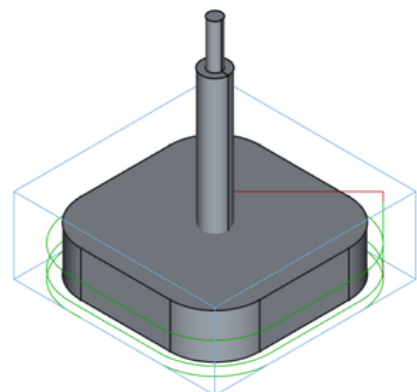
Due to the rounded corners, the Bool Nose Cutter is recommended. CAM workspace/Toolbar icon, then select the Bool Nose Cutter tool in the tool list that appears and add it to the job.



Step 5: Create a toolpath (Profile)

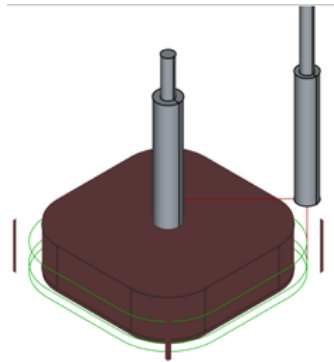
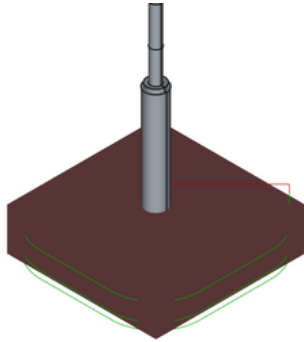
CAM workspace/Profile icon, then set the following:

Basic geometry: the model should be selected Depth: cutting depth (the model can be the full thickness, but machining can also be done in several steps) Heights: the safety height to which the tool moves between machining operations Operation: in the case of an external contour, the external profile.



Step 6: Check toolpath

On the CAM workspace, we can use the CAM Simulator to check the correctness of the toolpath.



Step 7: Create NC code

Postprocessor setup:

In the model tree, double-click on Job, then select the appropriate processor on the Output tab (e.g. in many cases this is grbl).

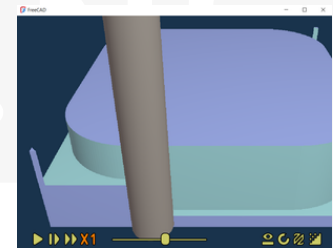
Post-processing:

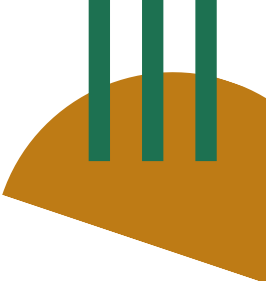
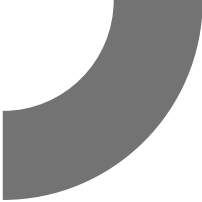
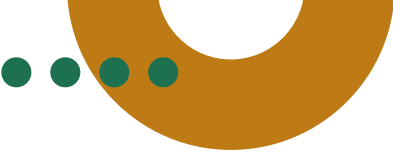
The Post-Processor function can be used to create the NC code in the CAM workspace. In the model tree, select the Job and then select the Post-Processor tool. The generated code will appear in a pop-up window and will be automatically saved with the .nc extension in the folder where the FreeCAD file is located.

Step 8: 3D simulation

In the CAM workspace with the CAM simulator or New CAM Simulator.

- Demonstrate how to run and analyze the simulation.
- Students simulate the CNC machining process with their own code.
- Identify and correct errors in the code that arise during simulation.





Evaluation and closing (5 minutes):

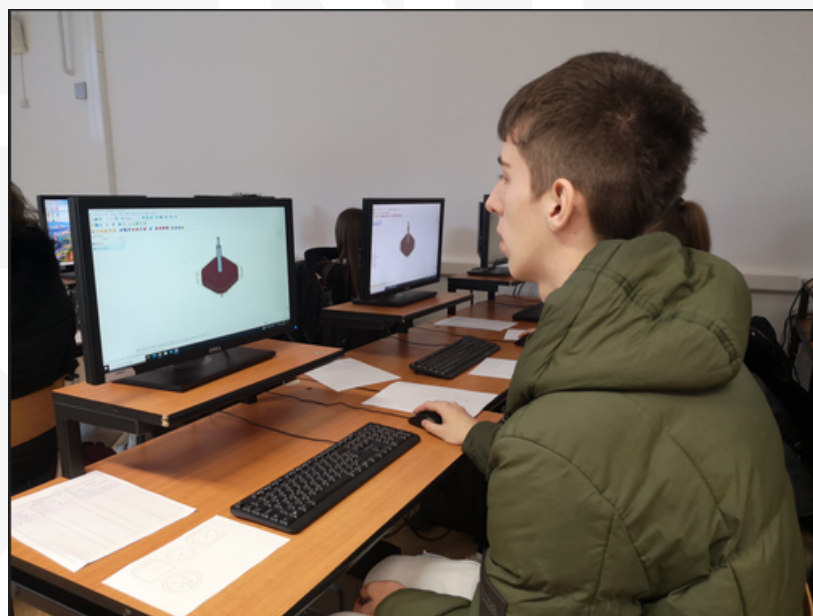
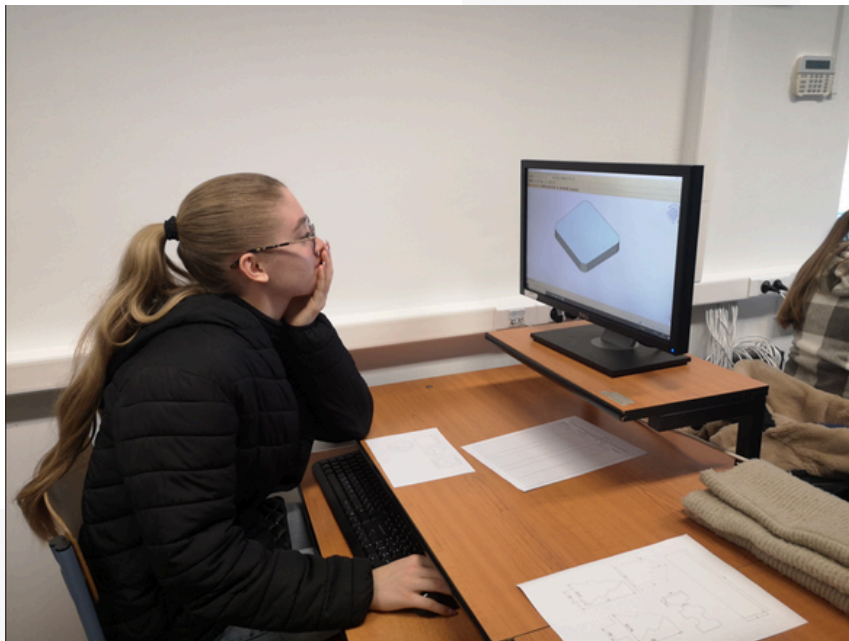
- Overview of the CNC code generation and 3D simulation process.
- Summary of what was learned.
- Brief evaluation of students' work.



Appendix

Photos of the implementation of the watch:

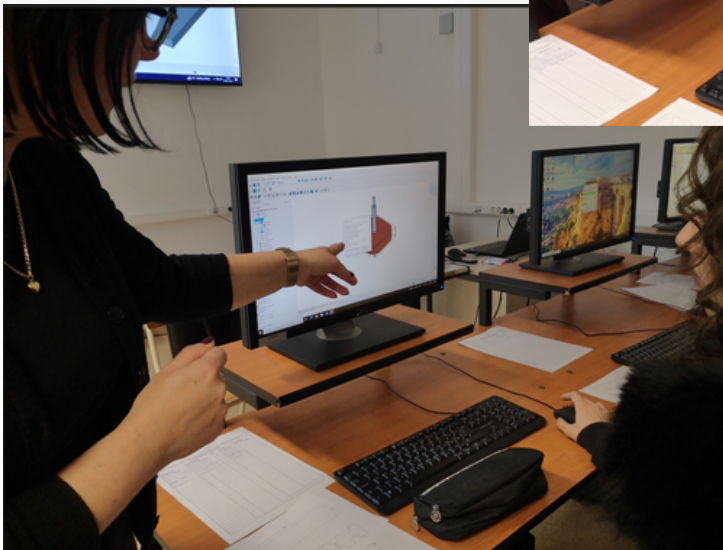
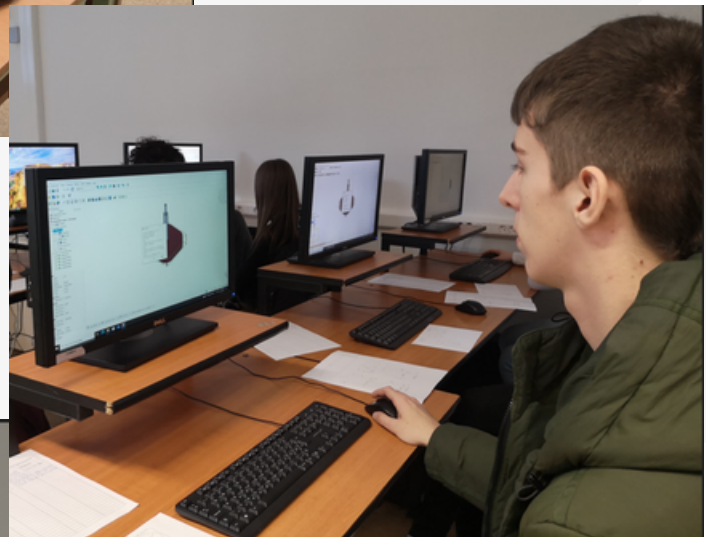
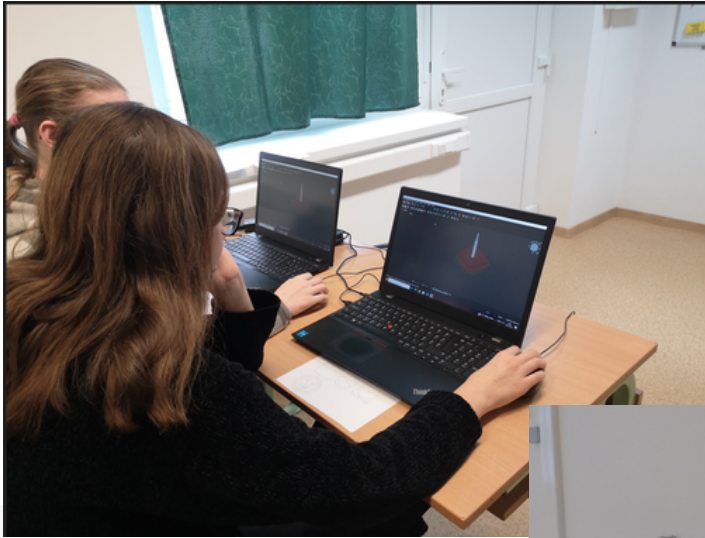
- Pictures of students working in FreeCAD



Appendix

Photos of the implementation of the watch:

- Pictures of students working in FreeCAD



Appendix

Student output:

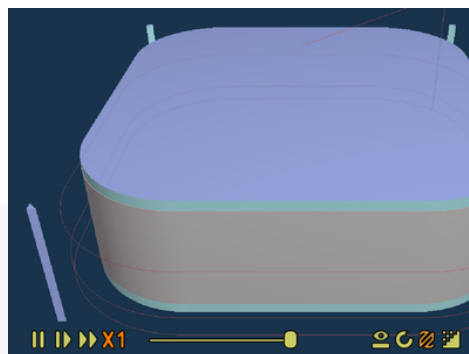
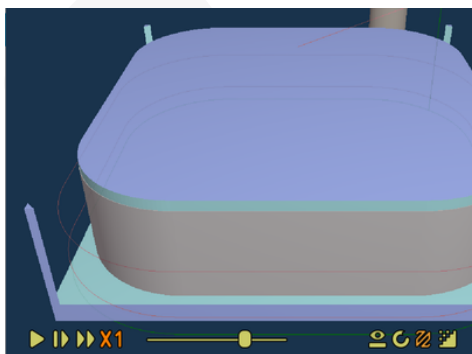
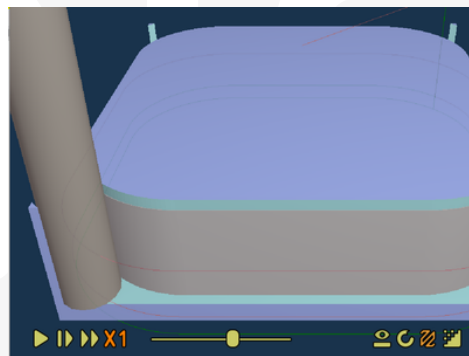
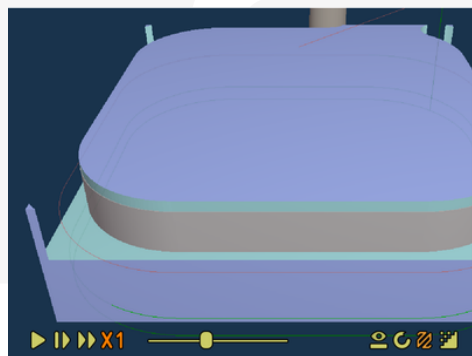
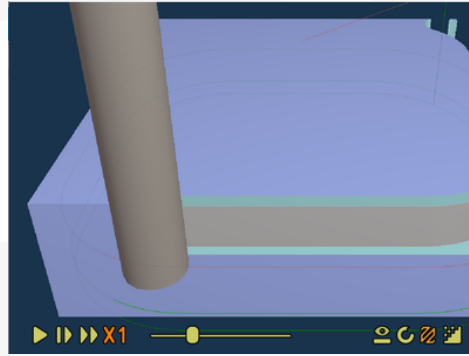
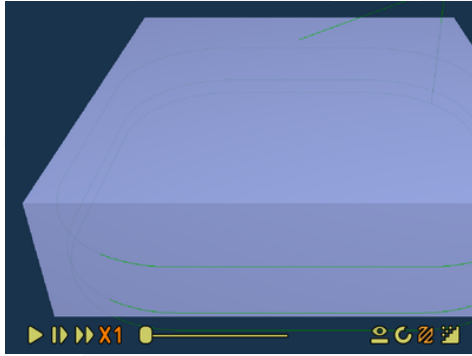
- NC code

G0 Z16.000 G0 X18.837 Y18.838 G0 Z14.000 G1 X18.837 Y18.838 Z6.000 G2 X22.498 Y10.109 Z6.000 I-8.840 J-8.839 K0.000 G1 X22.500 Y-10.000 Z6.000 G2 X10.109 Y-22.498 Z6.000 I-12.501 J0.003 K0.000 G1 X-10.000 Y-22.500 Z6.000 G2 X-22.498 Y-10.109 Z6.000 I0.003 J12.501 K0.000 G1 X-22.500 Y10.000 Z6.000 G2 X-10.109 Y22.498 Z6.000 I12.501 J-0.003 K0.000 G1 X10.000 Y22.500 Z6.000 G2 X18.837 Y18.838 Z6.000 I-0.003 J-12.501 K0.000 G1 X18.837 Y18.838 Z1.000 G2 X22.498 Y10.109 Z1.000 I-8.840 J-8.839 K0.000 G1 X22.500 Y-10.000 Z1.000 G2 X10.109 Y-22.498 Z1.000 I-12.501 J0.003 K0.000 G1 X-10.000 Y-22.500 Z1.000 G2 X-22.498 Y-10.109 Z1.000 I0.003 J12.501 K0.000 G1 X-22.500 Y10.000 Z1.000 G2 X-10.109 Y22.498 Z1.000 I12.501 J-0.003 K0.000 G1 X10.000 Y22.500 Z1.000 G2 X18.837 Y18.838 Z1.000 I-0.003 J-12.501 K0.000 G1 X18.837 Y18.838 Z-1.000 G2 X22.498 Y10.109 Z-1.000 I-8.840 J-8.839 K0.000 G1 X22.500 Y-10.000 Z-1.000 G2 X10.109 Y-22.498 Z-1.000 I-12.501 J0.003 K0.000 G1 X-10.000 Y-22.500 Z-1.000 G2 X-22.498 Y-10.109 Z-1.000 I0.003 J12.501 K0.000 G1 X-22.500 Y10.000 Z-1.000 G2 X-10.109 Y22.498 Z-1.000 I12.501 J-0.003 K0.000 G1 X10.000 Y22.500 Z-1.000 G2 X18.837 Y18.838 Z-1.000 I-0.003 J-12.501 K0.000 G0 Z16.000 G0 Z16.000 (Finish operation: Profile) (Begin postamble) M5 G17 G90 M2

Appendix

Student output:

- 3D simulation



Lesson plan

Subject:

CNC technology

Topic:

NC code design and CAD-CAM preparation for the production of a flower-shaped tray on a CNC machine

Learning objectives:

- Learn the functions needed to design a flower-shaped tray in AutoCAD.
- NC code generation and execution simulation on a CNC machine.

Required materials:

- Computers with installed software (AutoCAD, TPA CAD or FreeCAD, 3D simulator)
- Projector/interactive whiteboard
- Flower-shaped tray pattern

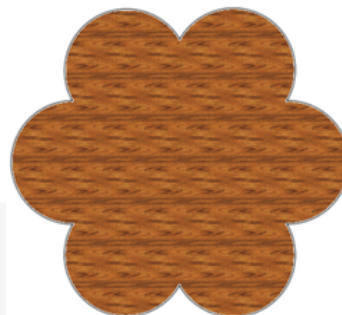
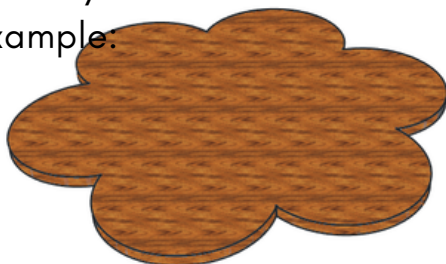
The structure of the lesson

Introduction (5 minutes):

Presentation of the flower-shaped tray project, description of objectives and expectations

The teacher shows the students a pattern for making a flower-shaped tray.

For example:



Together they plan the dimensions of the tray (diameter of the tray, thickness of the tray material).

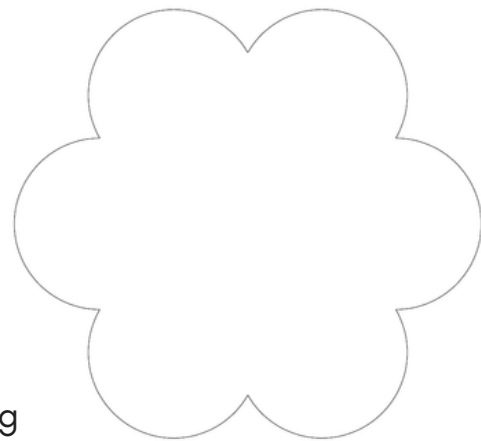
Transfer of new knowledge for designing in AutoCAD (5 minutes):

- *Learn about the polygon element to create an equilateral polygon*
- *Learn about the Arc element to create a semicircle by specifying the Start Point, Center Point, and End Point of the arc*
- Learn about the Rotate tool for rotating objects around a base point.

Using Rotate in conjunction with Copy.

Independent exercise - Creating a design for a flower-shaped tray in AutoCAD (15 minutes):

- Students will receive a printed copy of the attached blueprint.
- The dimensions in the drawing are established as discussed in the introductory section.
- Students save the completed drawing as a .dxf file.



The teacher will assist students in preparing the blueprint if necessary.

One possible way to make the drawing:

1. Step 2: Draw two perpendicular lines. Their intersection (M) will be the center of the tray.
2. Step 1: We draw a regular hexagon, the circumscribed circle of which is a circle with a radius of 150 units and the point M as the center. (Applying the polygon drawing element).
3. Step: Draw a semicircular arc over the side of the polygon as a diameter that is bisected by one of the auxiliary lines drawn in point 1. The starting point of the arc is one of the endpoints of the side, its center is the midpoint of the side, and its endpoint is the other endpoint of the side. (Applying an arc drawing element.)
4. Step 2: Rotate the drawn semicircle around point M as the base point by an angle of 60 degrees by choosing to rotate the copy of the selected object. (Apply the Rotate tool.) Repeat this copied rotation four more times.
5. Step 1: Erase the guide lines and the regular hexagon drawn in Step 1.
6. Step 2: Group the drawn arcs.

Independent practice - NC code creation, 3D simulation (15 minutes)

- Students load the .dxf file into their chosen CAD-CAM software.
- Students prepare the 3D model, create the necessary Jobs, define tools, generate toolpaths, and export NC code.
- Students will implement a 3D simulation of the CNC workflow.

Creating the NC code for the flower-shaped tray with FREECAD:

Step 1: Import the .dxf file containing the design into FREECAD.

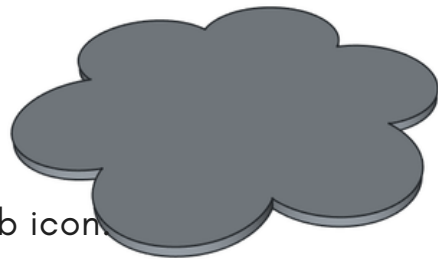
File/Import or File/Open/Import-Export/DXF/Apply

For further work, we turn on:

View/Panels/Model and View/Panels/Tasks

Step 2: Create a 3D model from the 2D design.

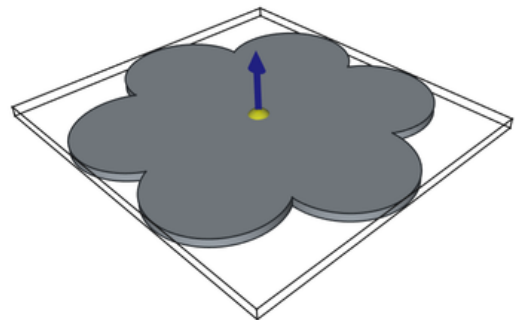
On the Part work surface, use the Extrude tool or Part Design workspace with the Block (Pad) tool Extrusion (blocking) amount: 10 mm, i.e. the thickness of the tray material will be 1 cm.



Step 3: Create a Job

In the CAM workspace, click the Create Job icon. The Model is selected during the Task creation process.

It is also recommended to set the coordinate system.



Step 4: Create a Tool

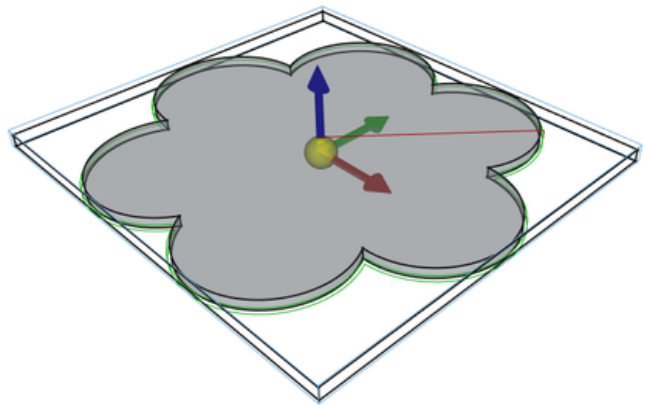
Due to the curves, the Bool Nose Cutter is recommended.

CAM workspace/Toolbar icon, then select the Bool Nose Cutter tool in the tool list that appears and add it to the job.

Step 5: Create a toolpath (Profile)

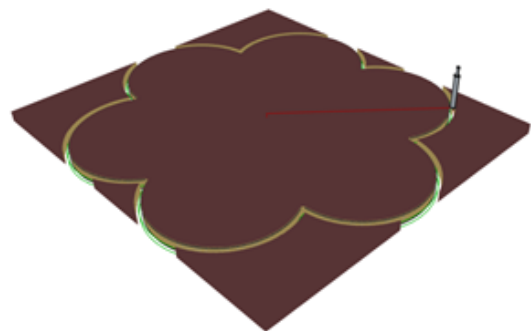
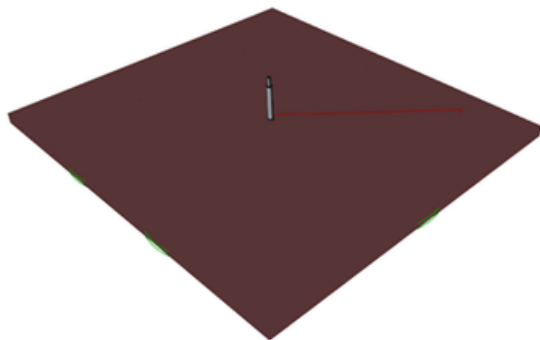
CAM workspace/Profile icon, then set the following:

Basic geometry: the model should be selected Depth: cutting depth (the model can be the full thickness, but machining can also be done in several steps) Heights: the safety height to which the tool moves between machining operations Operation: in the case of an external contour, the external profile.



Step 6: Check toolpath

On the CAM workspace, we can use the CAM Simulator to check the correctness of the toolpath.



Step 7: Create NC code

Postprocessor setup:

In the model tree, double-click on Job, then select the appropriate processor on the Output tab (e.g. in many cases this is grbl).

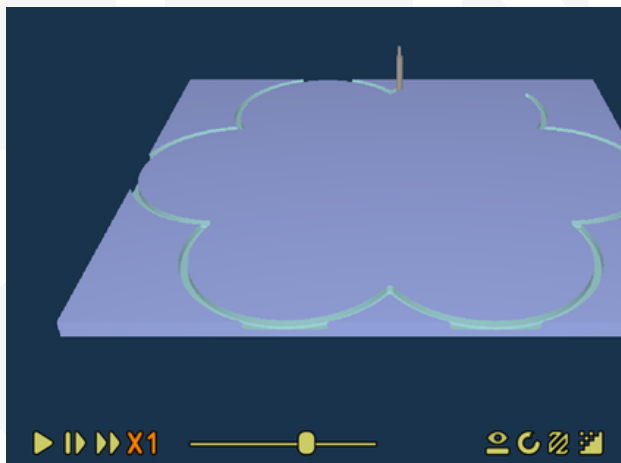
Post-processing:

The Post-Processor function can be used to create the NC code in the CAM workspace. In the model tree, select the Job and then select the Post-Processor tool. The generated code will appear in a pop-up window and will be automatically saved with the .nc extension in the folder where the FreeCAD file is located.

Step 8: 3D simulation

In the CAM workspace with the CAM simulator or New CAM Simulator.

- Demonstrate how to run and analyze the simulation.
- Students simulate the CNC machining process with their own code.
- Identify and correct errors in the code that arise during simulation.



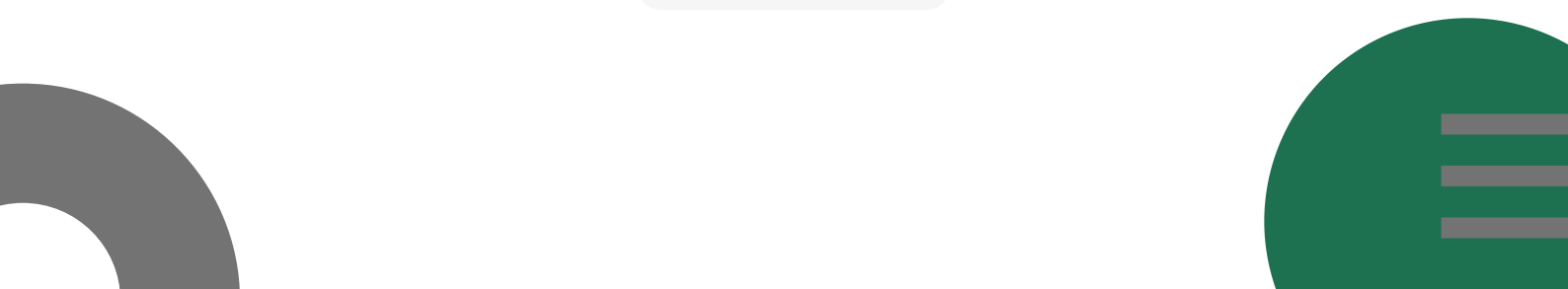


Evaluation and closing (5 minutes):

- Overview of the CNC code generation and 3D simulation process.
- Summary of what was learned.
- Brief evaluation of students' work.



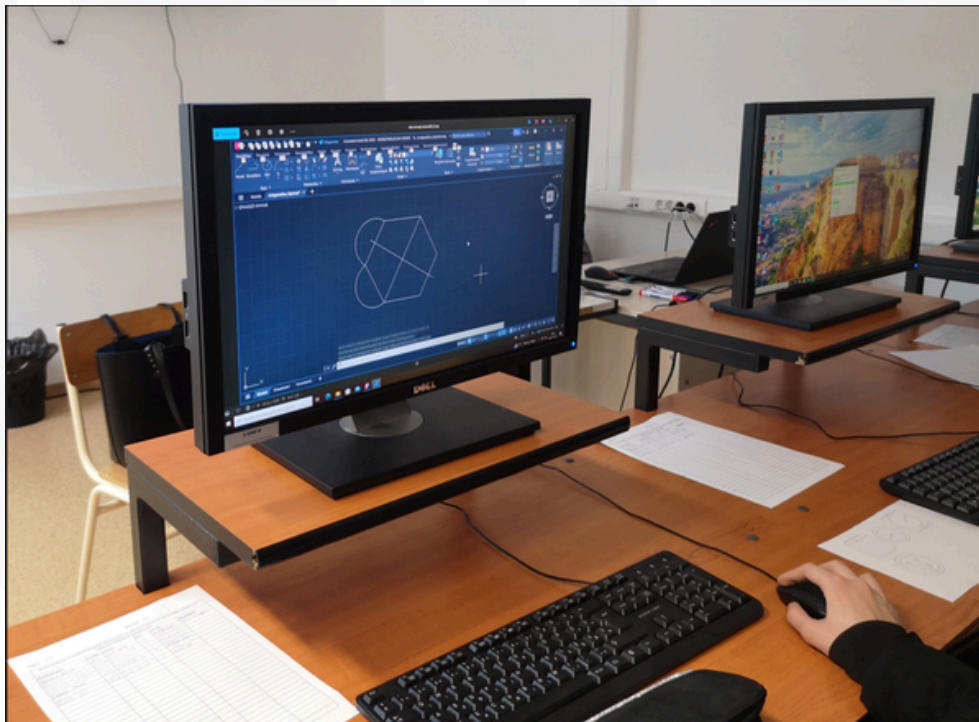
CNC



Appendix

Photos of the implementation of the watch:

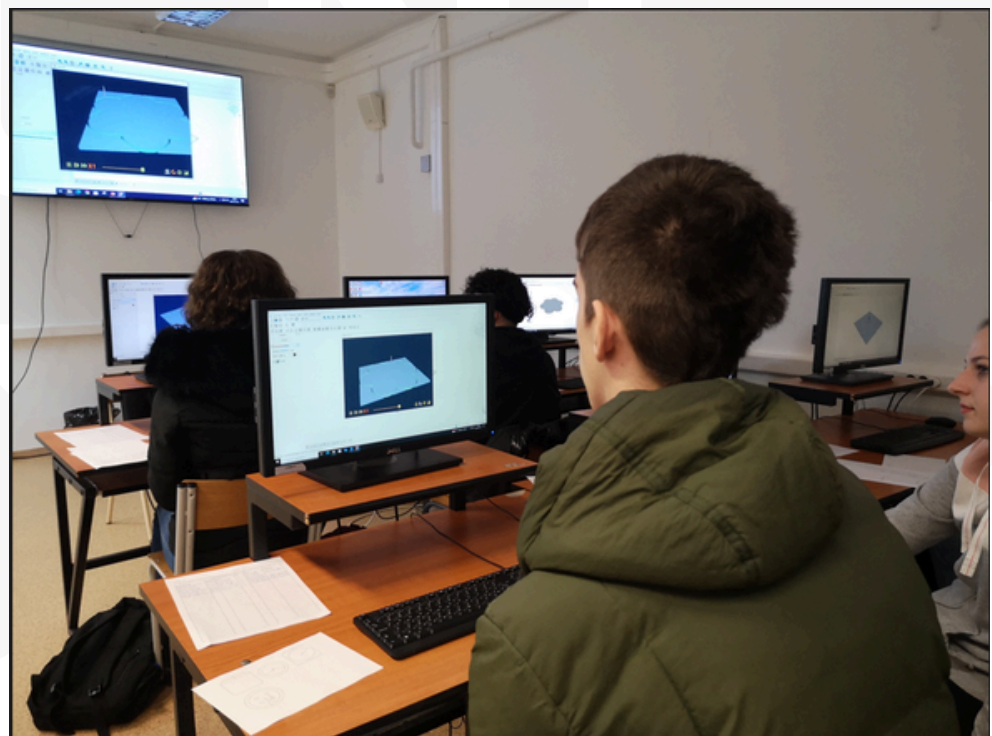
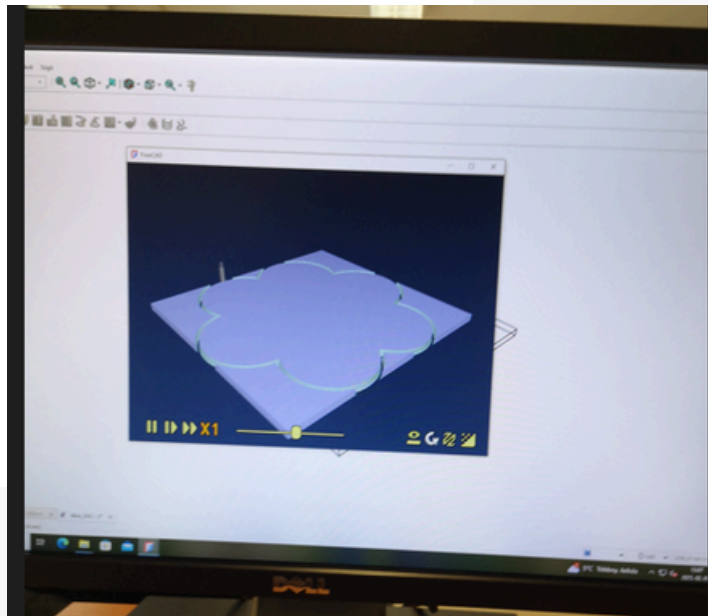
- Pictures of students working in AutoCAD and FreeCAD



Appendix

Photos of the implementation of the watch:

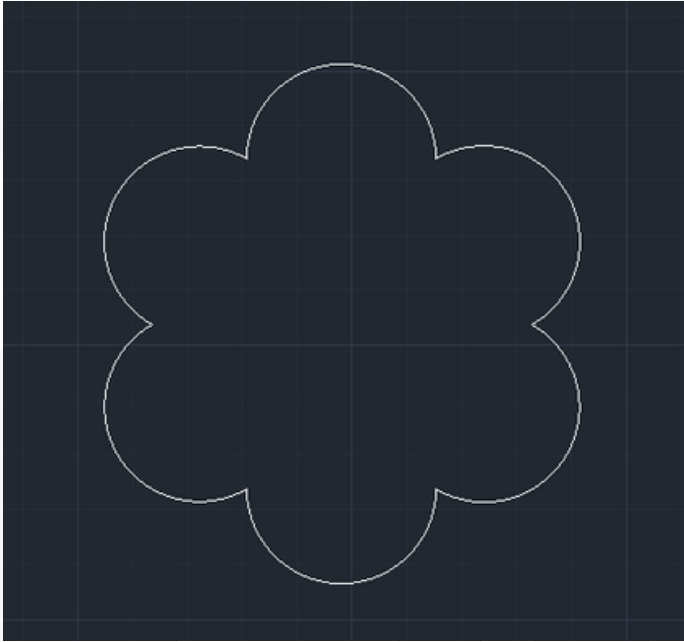
- Pictures of students working in AutoCAD and FreeCAD



Appendix

Student output:

- Drawing of a flower-shaped tray in AutoCAD



- NC code:

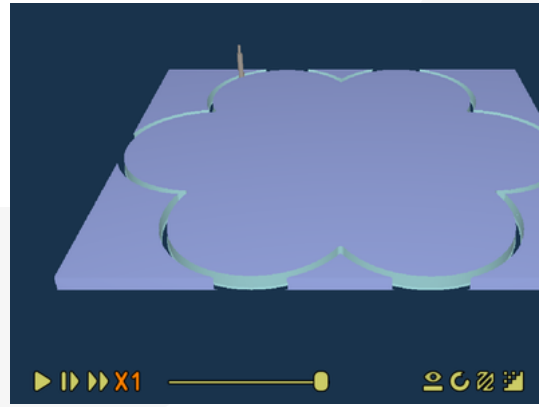
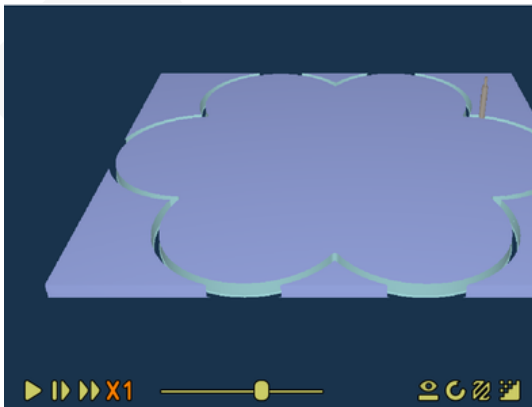
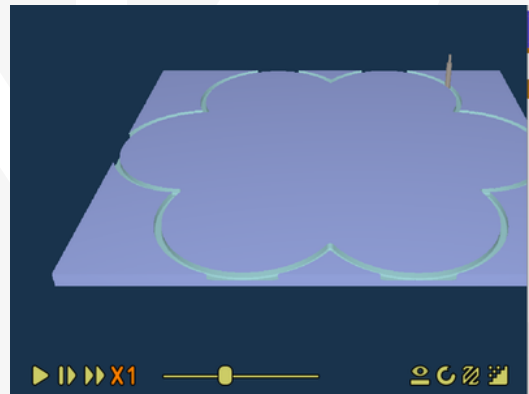
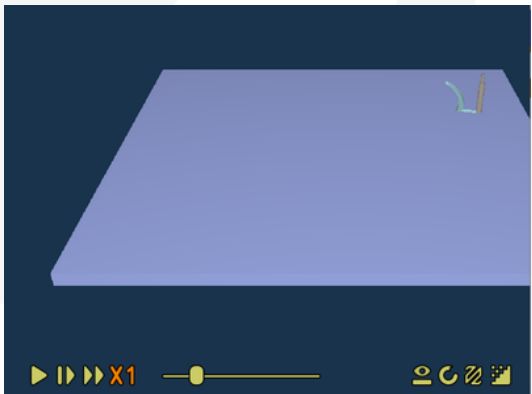
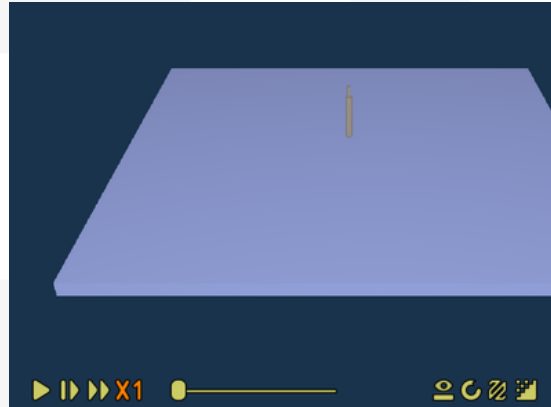
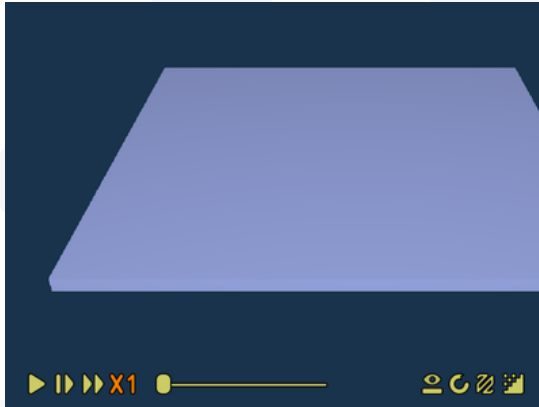
(Exported by FreeCAD) (Post Processor:
script_module) (Output Time:2025-02-01
23:43:14.141130) (Begin preamble) G17 G90 G21
(Begin operation: Fixture) (Path: Fixture) G54 (Finish
operation: Fixture) (Begin operation: 6 mm Bull
Nose001) (Path: 6 mm Bull Nose001) (6 mm Bull
Nose001) (Begin toolchange) (M6 T2) (Finish
operation: 6 mm Bull Nose001)

Appendix

(Begin operation: Profile) (Path: Profile) (Profile) (Compensated Tool Path.
Diameter: 6.0) G0 Z16.000 G0 X133.530 Y149.723 G0 Z14.000 G1 X133.530
Y149.723 Z5.000 G2 X134.849 Y77.872 Z5.000 I-68.426 J-37.194 K0.000 G2
X134.842 Y-77.871 Z5.000 I-4.468 J-77.872 K0.000 G2 X70.562 Y-190.414 Z5.000
I-69.959 J-34.671 K0.000 G2 X-0.364 Y-155.428 Z5.000 I-5.682 J77.868 K0.000 G2
X-134.389 Y-77.967 Z5.000 I-64.588 J42.925 K0.000 G2 X-134.706 Y77.786
Z5.000 I5.525 J77.888 K0.000 G2 X0.089 Y155.407 Z5.000 I70.435 J33.536 K0.000
G2 X133.530 Y149.723 Z5.000 I65.015 J-42.878 K0.000 G1 X133.530 Y149.723 Z-
1.000 G2 X134.849 Y77.872 Z-1.000 I-68.426 J-37.194 K0.000 G2 X134.842 Y-
77.871 Z-1.000 I-4.468 J-77.872 K0.000 G2 X70.562 Y-190.414 Z-1.000 I-69.959 J-
34.671 K0.000 G2 X-0.364 Y-155.428 Z-1.000 I-5.682 J77.868 K0.000 G2 X-
134.389 Y-77.967 Z-1.000 I-64.588 J42.925 K0.000 G2 X-134.706 Y77.786 Z-1.000
I5.525 J77.888 K0.000 G2 X0.089 Y155.407 Z-1.000 I70.435 J33.536 K0.000 G2
X133.530 Y149.723 Z-1.000 I65.015 J-42.878 K0.000 G0 Z16.000 G0 Z16.000 G0
X133.530 Y149.723 G0 Z14.000 G1 X133.530 Y149.723 Z5.000 G2 X134.849
Y77.872 Z5.000 I-68.426 J-37.194 K0.000 G2 X134.842 Y-77.871 Z5.000 I-4.468 J-
77.872 K0.000 G2 X70.562 Y-190.414 Z5.000 I-69.959 J-34.671 K0.000 G2 X-0.364
Y-155.428 Z5.000 I-5.682 J77.868 K0.000 G2 X-134.389 Y-77.967 Z5.000 I-64.588
J42.925 K0.000 G2 X-134.706 Y77.786 Z5.000 I5.525 J77.888 K0.000 G2 X0.089
Y155.407 Z5.000 I70.435 J33.536 K0.000 G2 X133.530 Y149.723 Z5.000 I65.015 J-
42.878 K0.000 G1 X133.530 Y149.723 Z-1.000 G2 X134.849 Y77.872 Z-1.000 I-
68.426 J-37.194 K0.000 G2 X134.842 Y-77.871 Z-1.000 I-4.468 J-77.872 K0.000 G2
X70.562 Y-190.414 Z-1.000 I-69.959 J-34.671 K0.000 G2 X-0.364 Y-155.428 Z-
1.000 I-5.682 J77.868 K0.000 G2 X-134.389 Y-77.967 Z-1.000 I-64.588 J42.925
K0.000 G2 X-134.706 Y77.786 Z-1.000 I5.525 J77.888 K0.000 G2 X0.089 Y155.407
Z-1.000 I70.435 J33.536 K0.000 G2 X133.530 Y149.723 Z-1.000 I65.015 J-42.878
K0.000 G0 Z16.000 G0 Z16.000 (Finish operation: Profile) (Begin postamble) M5
G17 G90 M2

Appendix

- 3D simulation:



Lesson plan

Subject:

CNC technology

Topic:

NC code design and CAD-CAM preparation for the production of wall key holders on a CNC machine - 1st lesson

Learning objectives:

- Learn the functions needed to design a wall key holder in AutoCAD.
- Creating drawings for the parts of the wall key holder in AutoCAD.

Required materials:

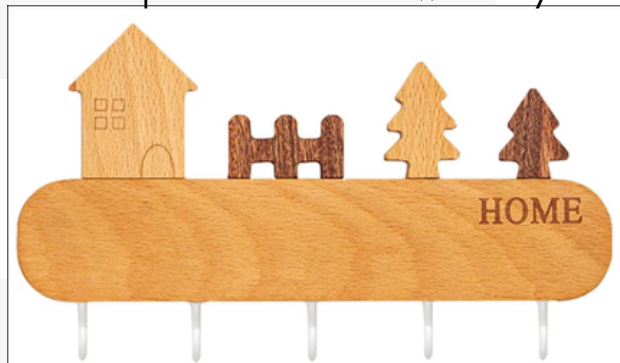
- Computers with AutoCAD software installed
- Projector/interactive whiteboard
- Wall key holder pattern

The structure of the lesson

Introduction (5 minutes):

Presentation of the wall key holder project, description of objectives and expectations

The teacher shows the students the pattern for the wall key holder to be made.



Together they discuss the thickness of wood and the dimensions of the individual parts of the key chain.

Guided practice - tips for designing in AutoCAD (10 minutes):

The teacher will introduce the following tools to the students, who will try them out with him/her.

- *Using the Fillet tool to round the edges of objects, the role of the fillet radius*
- *Use the Group tool to group objects, and the Ungroup tool to ungroup them.*
- *Learn about the Mirror tool to create a mirrored copy of selected objects*

The teacher points out how the tools learned can be used when drawing individual parts of the wall key holder.

Independent exercise - Creating individual parts of the keychain in AutoCAD (25 minutes):

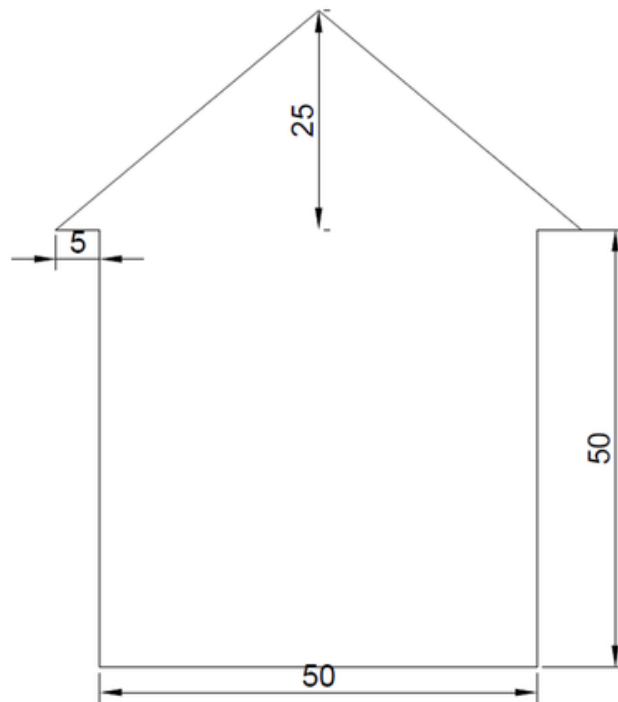
- Students will receive a printout of the blueprints with the attached dimensions.
- Students save the completed drawings one by one into a .dxf file.

The teacher assists students in preparing blueprints if necessary.

1_drawing: bottom of key holder (rectangle with rounded corners)



2_drawing: cottage



One possible way to draw:

Step 1: Draw the 50-unit long horizontal line, then the two 50-unit long lines perpendicular to it at its endpoints, then the two 5-unit long horizontal lines.

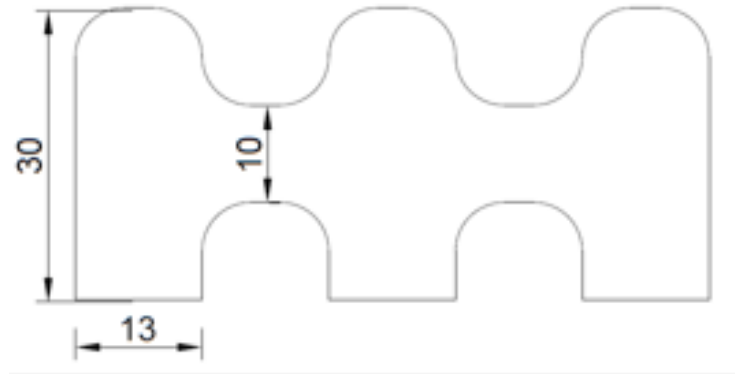
Step 2: At one end of the 50-unit long horizontal line, draw a 75-unit long vertical line and move it 25 units to the right.

Step 3: Connect the upper endpoint of the 75 unit long line to the endpoints of the 5 unit long lines.

Step 4: Delete the 75 unit long guide line.

Step 5: Group the elements of the drawing.

3_drawing: fence



Tip for faster implementation:

Step 1: Create the bottom part of the fence using 13 units of horizontal and 10 units of vertical lines.

Step 2: Make the necessary roundings.

Step 3: Group the prepared elements.

Step 4: Draw a perpendicular line 30 units long at both ends of the created object.

Step 5: We reflect the shape grouped in step 3 onto the line passing through the endpoints of the two perpendiculars, leaving the original shape intact.

Step 6: Ungroup the mirrored shape and round off both ends.

Step 7: Group the individual objects in the drawing.

4_drawing: tree_1

Tip for faster implementation:

Notice the axial symmetry of the shape!

Step 1: Draw a vertical guide line 70 units long. This will be the axis of symmetry of the tree.

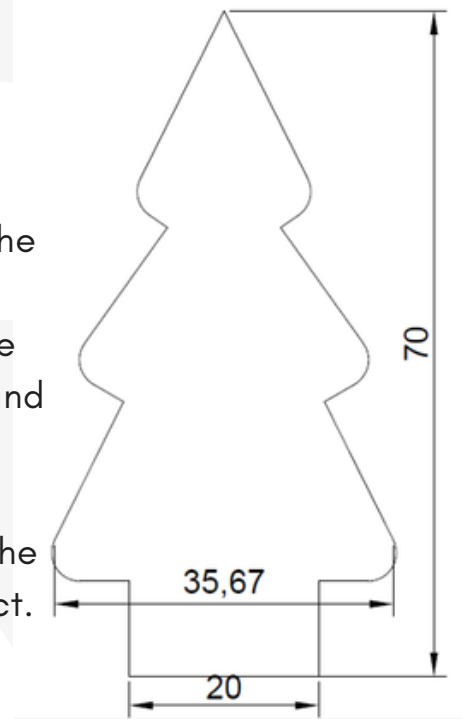
Step 2: To the left of the guide line, create the left side of the tree by drawing lines and making the necessary roundings.

Step 3: Group the left part of the tree.

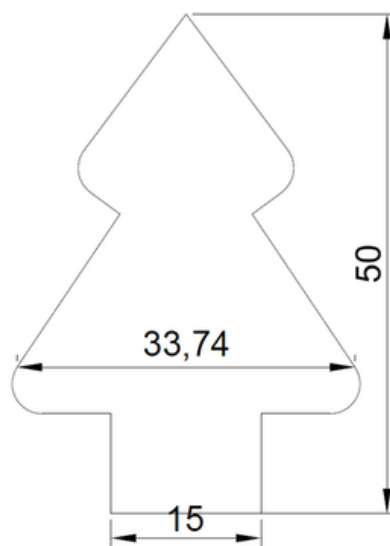
Step 4: Reflect the grouped object onto the guide line while keeping the original object.

Step 5: Delete the guide line.

6_ Group the parts of the tree.



5_drawing: tree_2



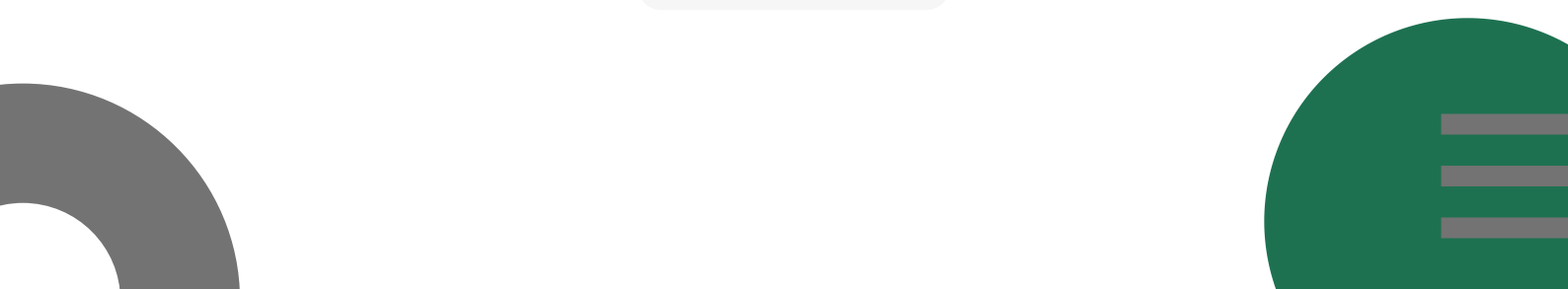


Evaluation and closing (5 minutes):

- Review of drawings made by students.
- Discussing possible design improvements.
- Summary of what was learned.
- Brief evaluation of students' work.



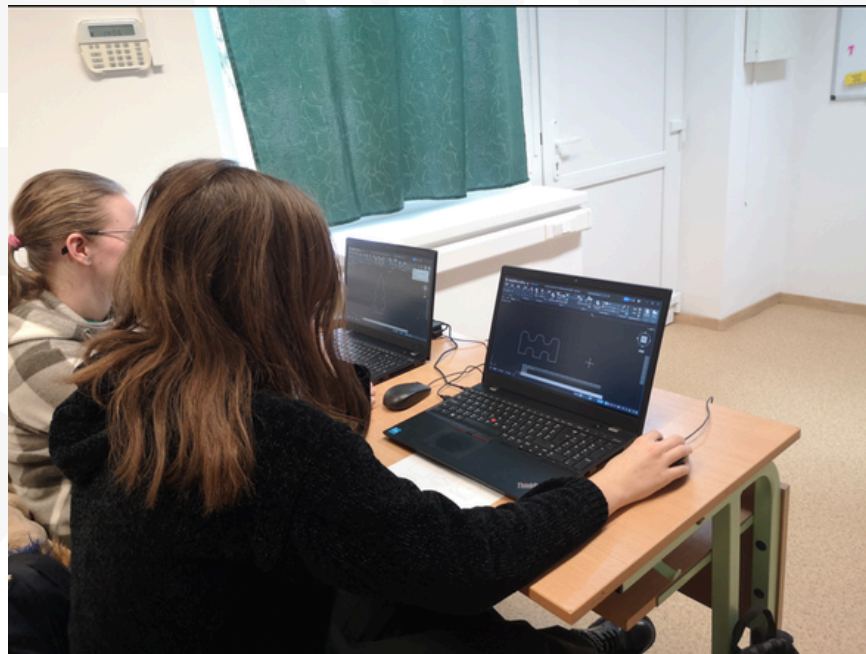
CNC



Appendix

Photos of the implementation of the watch:

- Pictures of students working in AutoCAD



Appendix

Photos of the implementation of the watch:

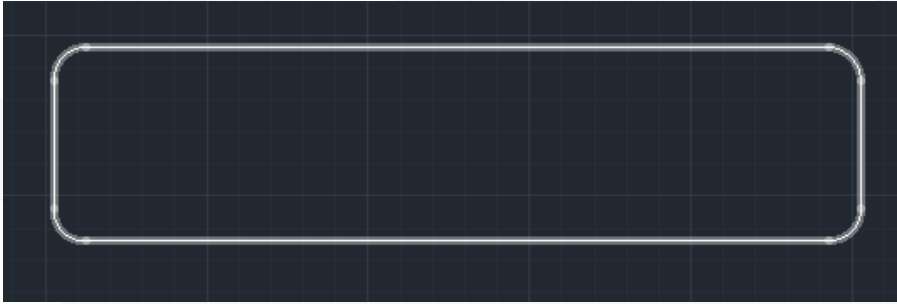
- Pictures of students working in AutoCAD



Appendix

Student output:

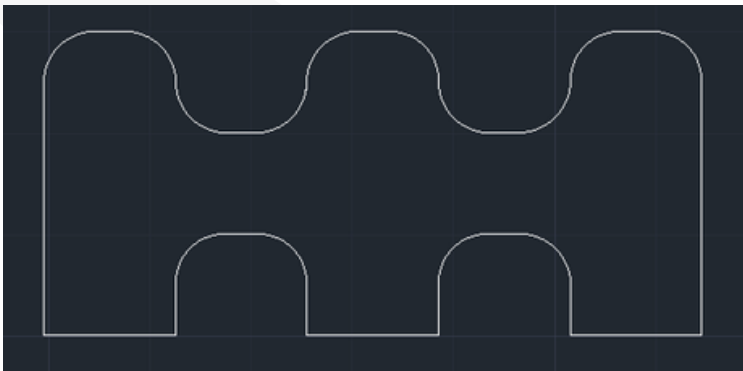
- 1_drawing (bottom of key ring) in AutoCAD



- 2_drawing (house) in AutoCAD



- 3_drawing (fence) in AutoCAD



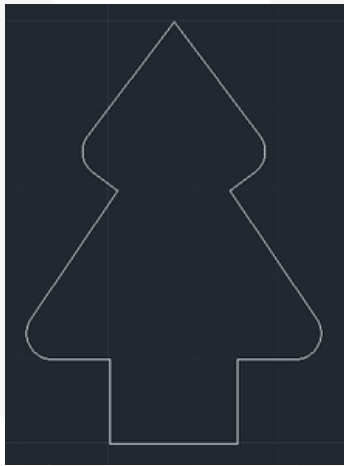
Appendix

Student output:

- 4_drawing (tree_1) in AutoCAD



- 5_drawing (fa_2) in AutoCAD



Lesson plan

Subject:

CNC technology

Topic:

NC code design and CAD-CAM preparation for the production of wall key holders on a CNC machine
- 2nd lesson

Learning objectives:

- Students practice generating NC code from designed drawings.
- Students practice creating a 3D simulation of the CNC machining process.

Required materials:

- Computers with NC code generation software, 3D simulator (e.g. FREECAD, which can be used to create NC code and basic also suitable for level simulation)
- Projector/interactive whiteboard
- Wall key holder made in the previous (1st) hour of the project - blueprints in .dxf format

The structure of the lesson

Introduction (5 minutes):

- Brief review of the previous lesson's material
- Overview of the CNC machining process

Independent practice - NC code creation, 3D simulation (35 minutes):

- Load the .dxf file into the selected CAD-CAM software.
- Create 3D model, Create Jobs, Define Tools, Generate Toolpaths, Export NC code, 3D simulation

Notes:

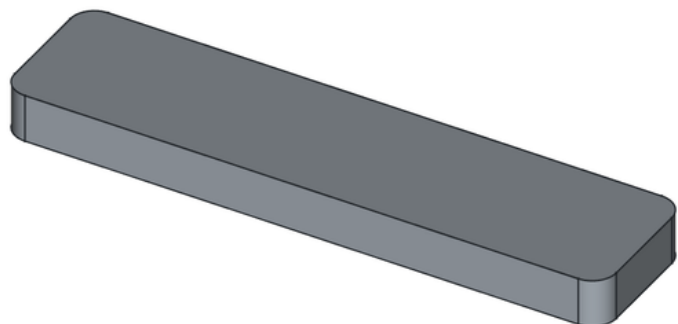
- The students are already familiar with the NC code generation and 3D simulation process, so they work independently. The teacher helps the students during their work as needed.
- The implementation can be done with the free downloadable FREECAD software, which is suitable for generating the CN code based on a 3D model and also for demonstrating basic CNC workflow simulation.

Creating the NC code for the bottom of the key holder (drawing 1) with FREECAD:

Step 1: Import the .dxf file containing the design into FREECAD.

Step 2: Create a 3D model from the 2D design.

On the Part workspace with the Extrude tool or on the Part Design workspace with the Pad tool. Extrusion (blocking) amount: 20 mm, meaning the material thickness will be 2 cm.



Step 3: Create a Job

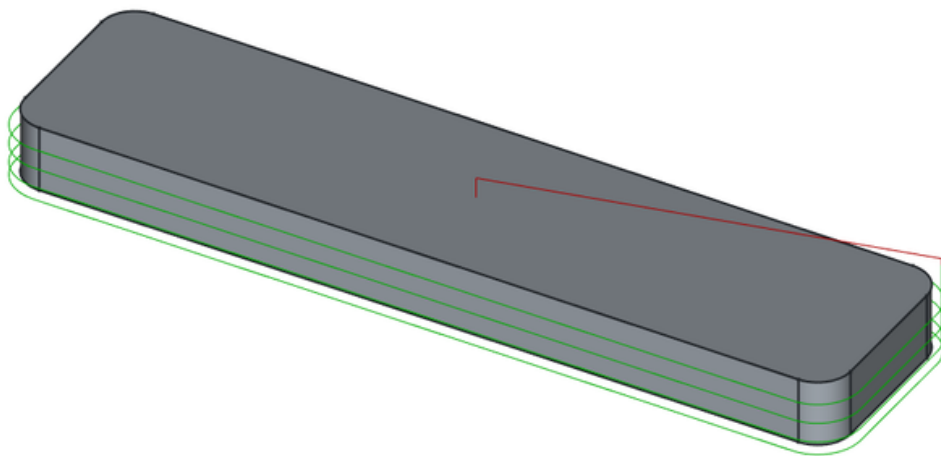
In the CAM workspace, click the Create Job icon.
The Model is selected during the Task creation process.
It is also recommended to set the coordinate system.

Step 4: Create a Tool

Due to the rounded corners, the Bool Nose Cutter is recommended.
CAM workspace/Toolbar icon, then select the Bool Nose Cutter tool in the tool list that appears and add it to the job.

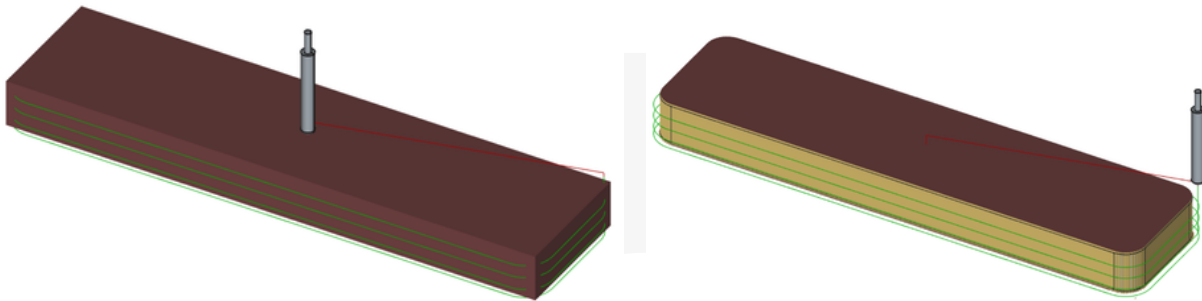
Step 5: Create a toolpath (Profile)

CAM workspace/Profile icon, then set the following:
Basic geometry: the model should be selected
Depth: cutting depth (the model can be the full thickness, but machining can also be done in several steps)
Heights: the safety height to which the tool moves between machining operations
Operation: in the case of an external contour, the external profile.



Step 6: Check toolpath

On the CAM workspace, we can use the CAM Simulator to check the correctness of the toolpath.



Step 7: Create NC code

Postprocessor setup:

In the model tree, double-click on Job, then select the appropriate processor on the Output tab (e.g. in many cases this is grbl).

Post-processing:

The Post-Processor function can be used to create the NC code in the CAM workspace. In the model tree, select the Job and then select the Post-Processor tool. The generated code will appear in a pop-up window and will be automatically saved with the .nc extension in the folder where the FreeCAD file is located.

Step 8: 3D simulation

In the CAM workspace with the CAM simulator or New CAM Simulator.

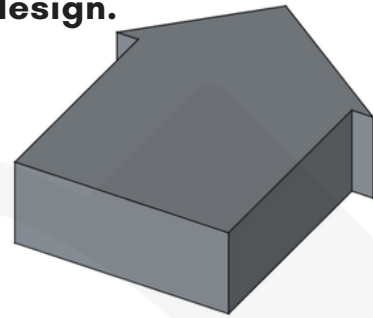
- Demonstrate how to run and analyze the simulation.
- Students simulate the CNC machining process with their own code.
- Identify and correct errors in the code that arise during simulation.



Creating the NC code for a house (2_drawing) with FreeCAD:

Step 1: Import the .dxf file containing the design.

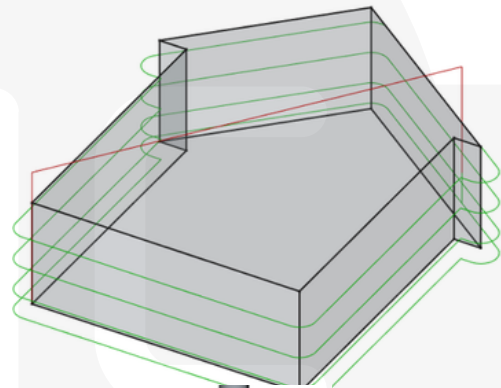
Step 2: Create the 3D model.



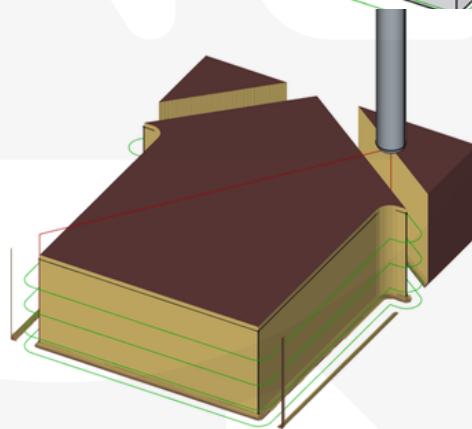
Step 3: Create a Job.

Step 4: Create a Tool.

Step 5: Create a toolpath (Profile).

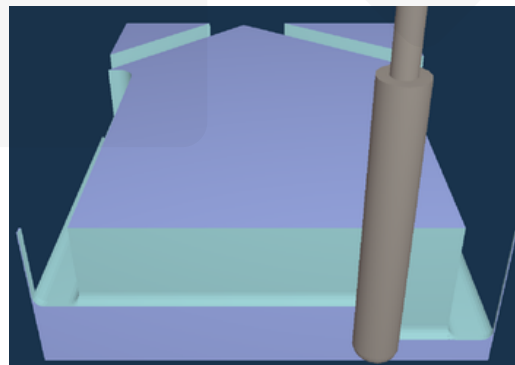


Step 6: Check toolpath.



Step 7: Create NC code.

Step 8: 3D simulation



Creating the NC code for a fence (3_drawing) with FreeCAD:

Step 1: Import the .dxf file containing the design.

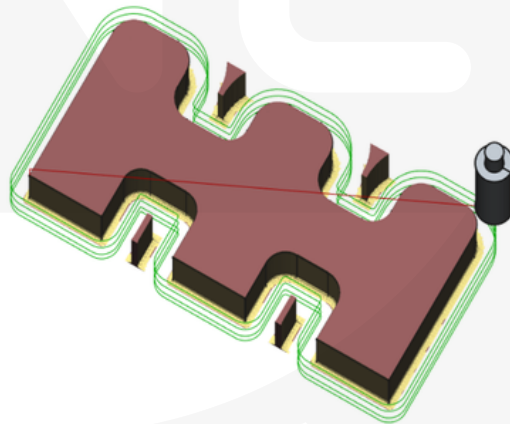
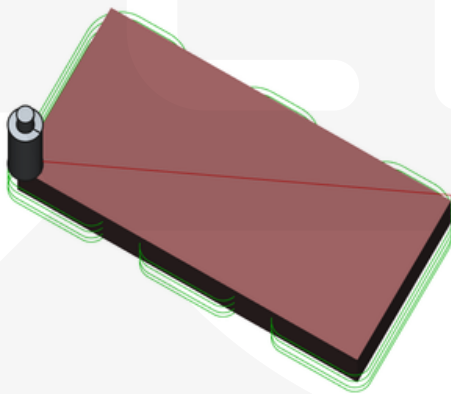
Step 2: Create the 3D model.

Step 3: Create a Job.

Step 4: Create a Tool.

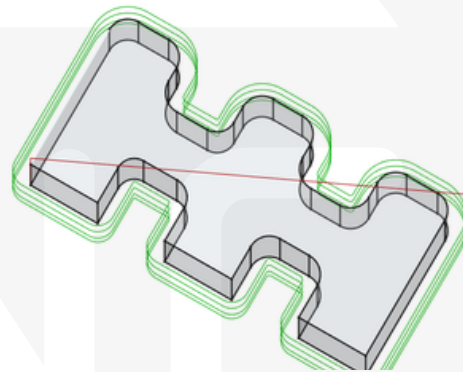
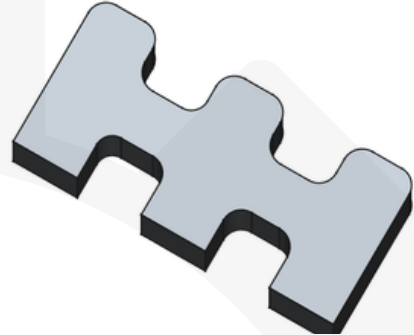
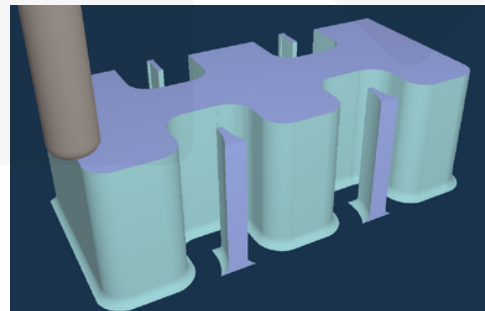
Step 5: Create a toolpath (Profile).

Step 6: Check toolpath.



Step 7: Create NC code.

Step 8: 3D simulation



Creating the NC code for Fa_1 (4_drawing) with FreeCAD:

Step 1: Import the .dxf file containing the design.

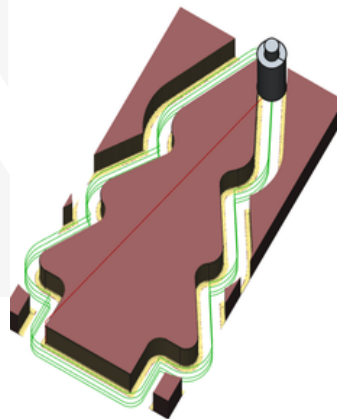
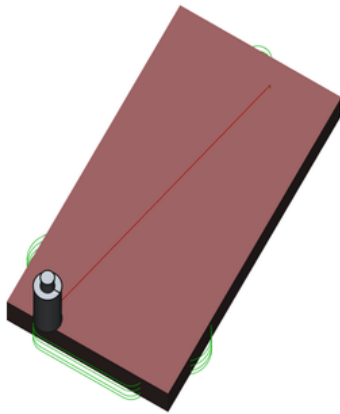
Step 2: Create the 3D model.

Step 3: Create a Job.

Step 4: Create a Tool.

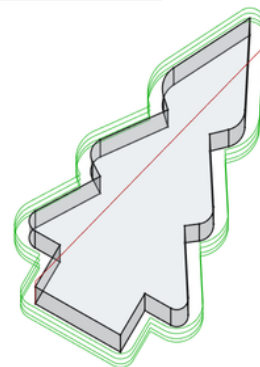
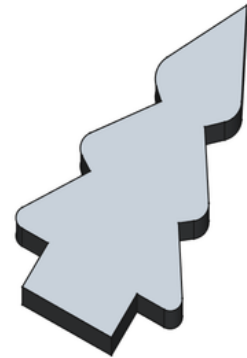
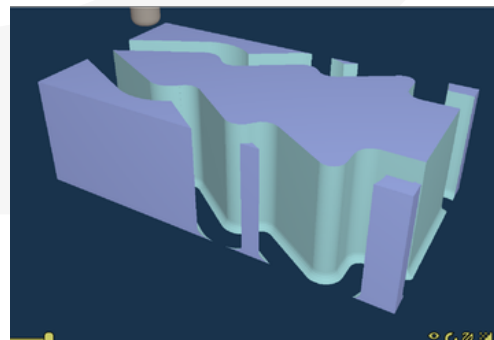
Step 5: Create a toolpath (Profile).

Step 6: Check toolpath.



Step 7: Create NC code.

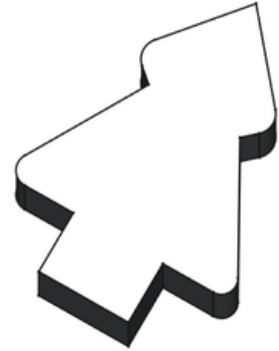
Step 8: 3D simulation



Creating the NC code for Fa_2 (5_drawing) with FreeCAD:

Step 1: Import the .dxf file containing the design.

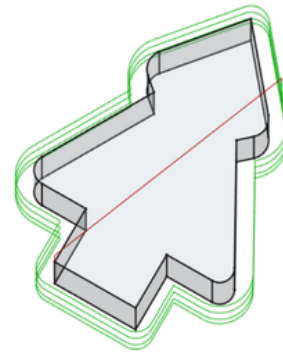
Step 2: Create the 3D model.



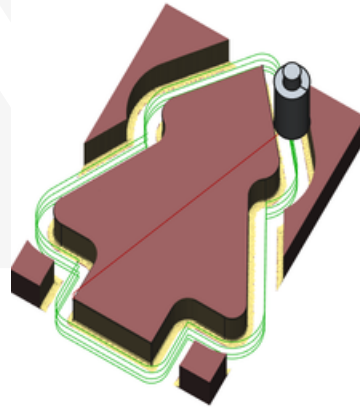
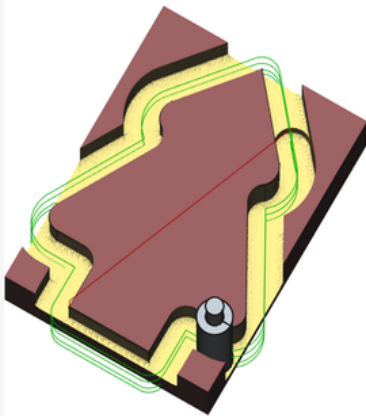
Step 3: Create a Job.

Step 4: Create a Tool.

Step 5: Create a toolpath (Profile).

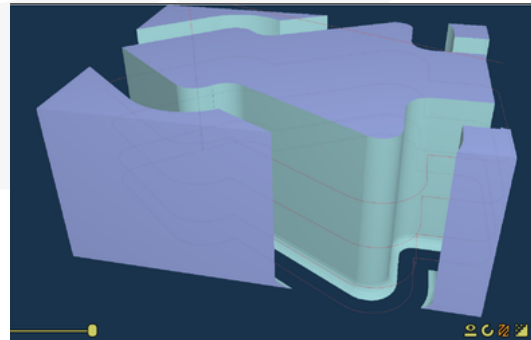


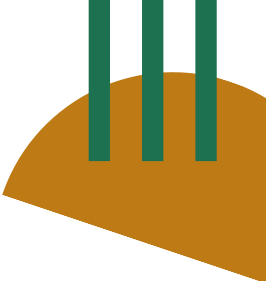
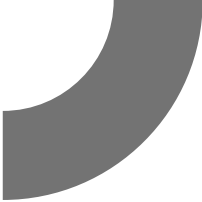
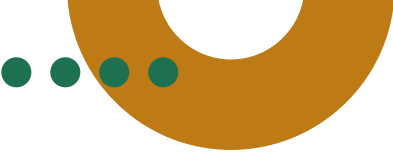
Step 6: Check toolpath.



Step 7: Create NC code.

Step 8: 3D simulation





Evaluation and closing (5 minutes):

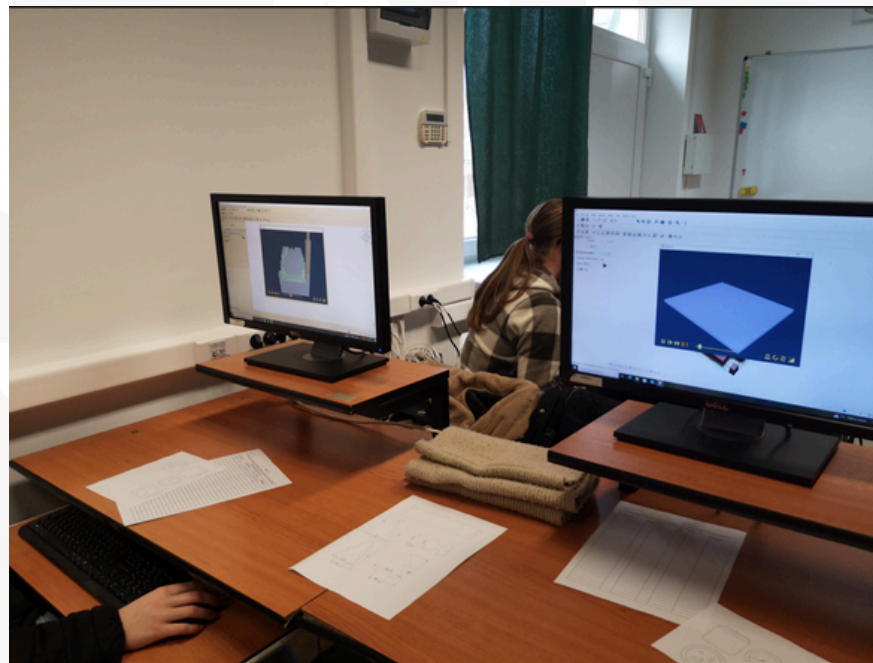
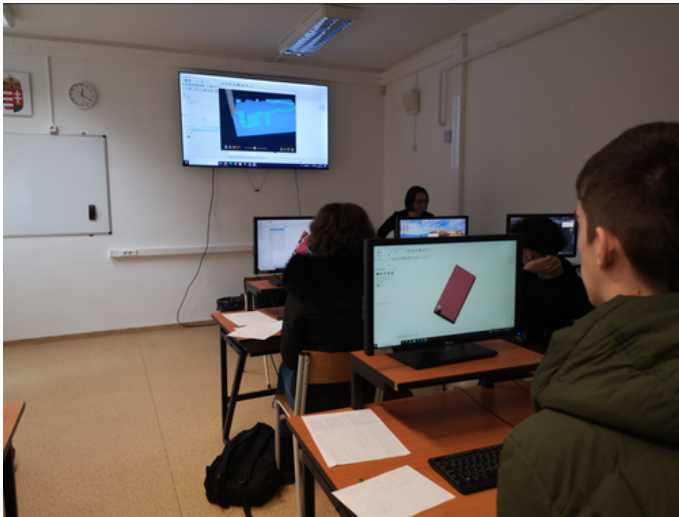
- Overview of the CNC code generation and 3D simulation process.
- Summary of what was learned.
- Brief evaluation of students' work.



Appendix

Photos of the implementation of the watch:

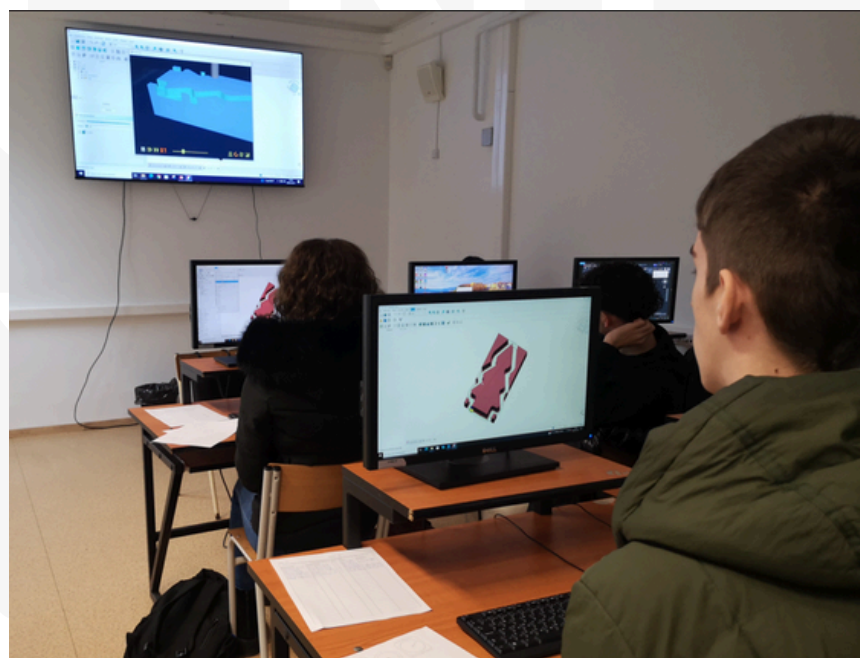
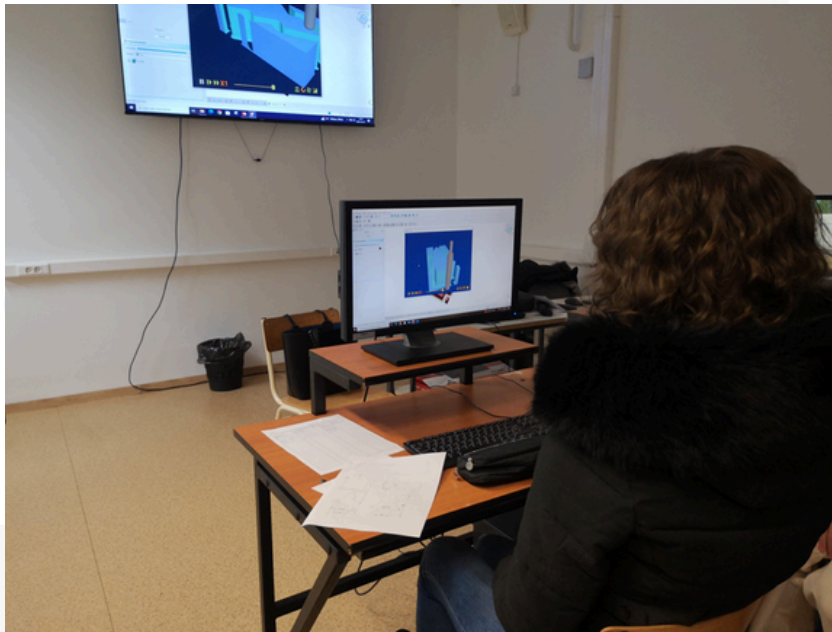
- Pictures of students working in FREECAD



Appendix

Photos of the implementation of the watch:

- Pictures of students working in FREECAD



Student output:

- **Key ring base - NC code**

(Exported by FreeCAD) (Post Processor: script module)

(Output Time:2025-02-02 15:24:31.419404) (Begin preamble)

G17 G90 G21 (Begin operation: Fixture) (Path3 Fixture) G54

(Finish operation: Fixture) (Begin operation: 613.002 kg)

Nose001) (Path: 6 mm Bull Nose001) (6 mm Bull Nose001)

(Begin toolchange) (M6 T2) (Finish operation: 6 mm Bull

Nose001) (Begin operation: Profile) (Path: Profile) (Profile)

(Compensated Tool Path. Diameter: 6.0) X128.000 Y-20.

G0 Z26.000 G0 X124.191 Y29.191 G0 Z24.000 G1 X124.191 Y29.191 Z15.000 G2 X127.997 Y20.131 Z15.000 I-9.194 J-9.193 K0.000 G1 X128.000 Y-20.000 Z15.000 G2 X115.131 Y-32.997 Z3.000 I-13.002 J0.004 K0.000 G1 X-115.000 Y-33.000 Z3.000 G2 X-127.997 Y-20.131 Z9.000 I0.004 J13.002 K0.000 G1 X-128.000 Y20.000 Z9.000 G2 X-115.131 Y32.997 Z9.000 I13.002 J-0.004 K0.000 G1 X115.000 Y33.000 Z9.000 G2 X124.191 Y29.191 Z9.000 I-0.004 J-13.002 K0.000 G1 X124.191 Y29.191 Z9.000 G2 X127.997 Y20.131 Z9.000 I-9.194 J-9.193 K0.000 G1 X128.000 Y-20.000 Z9.000 G2 X115.131 Y-32.997 Z9.000 I-13.002 J0.004 K0.000 G1 X-115.000 Y-33.000 Z9.000 G2 X-127.997 Y-20.131 Z9.000 I0.004 J13.002 K0.000 G1 X-128.000 Y20.000 Z9.000 G2 X-115.131 Y32.997 Z3.000 I13.002 J-0.004 K0.000 G1 X115.000 Y33.000 Z3.000 G2 X124.191 Y29.191 Z3.000 I-0.004 J-13.002 K0.000 G1 X124.191 Y29.191 Z-1.000 G2 X127.997 Y20.131 Z-1.000 I-9.194 J-9.193 K0.000 G1 X128.000 Y-20.000 Z-1.000 G2 X115.131 Y-32.997 Z-1.000 I-13.002 J0.004 K0.000 G1 X-115.000 Y-33.000 Z-1.000 G2 X-127.997 Y-20.131 Z-1.000 I0.004 J13.002 K0.000 G1 X-128.000 Y20.000 Z-1.000 G2 X-115.131 Y32.997 Z-1.000 I13.002 J-0.004 K0.000 G1 X115.000 Y33.000 Z-1.000 G2 X124.191 Y29.191 Z-1.000 I-0.004 J-13.002 K0.000 G0 Z26.000 G0 Z26.000 (Finish operation: Profile) (Begin postamble) M5 G17 G90 M2

Appendix

Student output:

- **Cottage - NC code**

(Exported by FreeCAD) (Post Processor: script_module) G1 X-3.000 Y47.000 Z9.000 G1 X-5.000 Y47.000 Z9.000 G2
(Output Time:2025-02-02 16:01:16.151834) (Begin preamble) X-7.129 Y52.114 Z9.000 I-0.000 J3.000 K0.000 G1 X17.866
G17 G90 G21 (Begin operation: Fixture) (Path: Fixture) G54 Y77.292 Z9.000 G2 X21.747 Y77.614 Z9.000 I2.129 J-2.114
(Finish operation: Fixture) (Begin operation: 6 mm Bull Nose001) (Path: 6 mm Bull Nose001) (6 mm Bull Nose001) K0.000 G1 X45.371 Y60.621 Z9.000 G1 X45.371 Y60.621
(Begin toolchange) (M6 T2) (Finish operation: 6 mm Bull Nose001) (Begin operation: Profile) (Path: Profile) (Profile) Z3.000 G1 X56.752 Y52.435 Z3.000 G2 X55.000 Y47.000
(Compensated Tool Path. Diameter: 6.0) G0 Z26.000 G0 Z3.000 I-1.752 J-2.435 K0.000 G1 X53.000 Y47.000 Z3.000
X45.371 Y60.621 G0 Z24.000 G1 X45.371 Y60.621 Z15.000 G1 X53.000 Y47.000 Z15.000 I-0.000 J3.000 K0.000 G1 X17.866 Y77.292 Z3.000
X56.752 Y52.435 Z15.000 G2 X55.000 Y47.000 Z15.000 I-1.752 J-2.435 K0.000 G1 X53.000 Y47.000 Z15.000 I-0.000 J3.000 K0.000 G1 X17.866 Y77.292 Z3.000
J-2.435 K0.000 G1 X53.000 Y47.000 Z15.000 G1 X53.000 Y47.000 Z15.000 I-0.000 J3.000 K0.000 G1 X17.866 Y77.292 Z3.000
Z15.000 G2 X50.000 Y-3.000 Z15.000 I-3.000 J0.000 K0.000 G1 X50.000 Y-3.000 Z15.000 I-0.000 J2.435 K0.000 G1 X53.000 Y47.000 Z-1.000 G1
X0.000 Y-3.000 Z15.000 G2 X-3.000 Y0.000 Z15.000 I0.000 J-2.435 K0.000 G1 X53.000 Y47.000 Z-1.000 G1
J3.000 K0.000 G1 X-3.000 Y47.000 Z15.000 G1 X-5.000 Y47.000 Z-1.000 G2 X50.000 Y-3.000 Z-1.000 I-3.000
Z15.000 G2 X-7.129 Y52.114 Z15.000 I-0.000 J3.000 K0.000 G1 X0.000 Y-3.000 Z-1.000 G2 X-3.000 Y0.000
X17.866 Y77.292 Z15.000 G2 X21.747 Y77.614 Z15.000 I2.129 J-2.114 K0.000 G1 X-3.000 Y47.000 Z-1.000
2.114 K0.000 G1 X45.371 Y60.621 Z15.000 G1 X45.371 Y60.621 Y47.000 Z-1.000 G2 X-7.129 Y52.114 Z-1.000 I-
Z9.000 G1 X56.752 Y52.435 Z9.000 G2 X55.000 Y47.000 Z9.000 K0.000 G1 X17.866 Y77.292 Z-1.000 G2
I-1.752 J-2.435 K0.000 G1 X53.000 Y47.000 Z9.000 G1 X53.000 Y77.614 Z-1.000 I2.129 J-2.114 K0.000 G1 X45.371
Y0.000 Z9.000 G2 X50.000 Y-3.000 Z9.000 I-3.000 J0.000 K0.000 G0 Z26.000 G0 Z26.000 (Finish operation:
G1 X0.000 Y-3.000 Z9.000 G2 X-3.000 Y0.000 Z9.000 I0.000 J-2.435 K0.000 G1 X53.000 Y47.000 Z-1.000 G1
J3.000 K0.000 (Begin postamble) M5 G17 G90
M2

Appendix

Student output: Fa_1 NC code

```
|(Exported by FreeCAD)
(Post Processor: script_module)
(Output Time:2025-02-02 17:17:14.999502)
(Begin preamble)
G17 G90
G21
(Begin operation: Fixture)
(Path: Fixture)
G54
(Finish operation: Fixture)
(Begin operation: 6 mm Bull Nose001)
(Path: 6 mm Bull Nose001)
(6 mm Bull Nose001)
(Begin toolchange)
( M6 T2 )
(Finish operation: 6 mm Bull Nose001)
(Begin operation: Profile)
(Path: Profile)
(Profile)
(Compensated Tool Path. Diameter: 6.0)
G0 Z26.000
G0 X15.866 Y65.078
G0 Z24.000
G1 X15.866 Y65.078 Z15.000
G1 X21.332 Y54.319 Z15.000
G2 X20.383 Y46.240 Z15.000 I-6.561 J-3.324 K0.000
G2 X18.791 Y44.657 Z15.000 I-13.488 J11.966 K0.000
G1 X25.652 Y34.089 Z15.000
G2 X24.014 Y25.438 Z15.000 I-5.357 J-3.466 K0.000
G1 X30.607 Y15.209 Z15.000
G2 X26.098 Y6.938 Z15.000 I-4.518 J-2.902 K0.000
G1 X23.000 Y6.938 Z15.000
G1 X23.000 Y0.000 Z15.000
G2 X20.000 Y-3.000 Z15.000 I-3.000 J0.000 K0.000
G1 X0.000 Y-3.000 Z15.000
G2 X-3.000 Y0.000 Z15.000 I0.000 J3.000 K0.000
G1 X-3.000 Y7.000 Z15.000
G1 X-5.852 Y7.000 Z15.000
G2 X-10.413 Y15.153 Z15.000 I0.009 J5.357 K0.000
G1 X-4.089 Y25.451 Z15.000
G1 X-4.482 Y25.705 Z15.000
G2 X-6.306 Y34.519 Z15.000 I3.448 J5.310 K0.000
```

Appendix

Student output: Fa_1 NC code (continued)

G1 X1.071 Y44.823 Z15.000
G2 X-1.050 Y54.517 Z15.000 I5.258 J6.230 K0.000
G1 X7.314 Y71.337 Z15.000
G2 X12.675 Y71.359 Z15.000 I2.686 J-1.337 K0.000
G1 X15.866 Y65.078 Z15.000
G1 X15.866 Y65.078 Z9.000
G1 X21.332 Y54.319 Z9.000
G2 X20.383 Y46.240 Z9.000 I-6.561 J-3.324 K0.000
G2 X18.791 Y44.657 Z9.000 I-13.488 J11.966 K0.000
G1 X25.652 Y34.089 Z9.000
G2 X24.014 Y25.438 Z9.000 I-5.357 J-3.466 K0.000
G1 X30.607 Y15.209 Z9.000
G2 X26.098 Y6.938 Z9.000 I-4.518 J-2.902 K0.000
G1 X23.000 Y6.938 Z9.000
G1 X23.000 Y0.000 Z9.000
G2 X20.000 Y-3.000 Z9.000 I-3.000 J0.000 K0.000
G1 X0.000 Y-3.000 Z9.000
G2 X-3.000 Y0.000 Z9.000 I0.000 J3.000 K0.000
G1 X-3.000 Y7.000 Z9.000
G1 X-5.852 Y7.000 Z9.000
G2 X-10.413 Y15.153 Z9.000 I0.009 J5.357 K0.000
G1 X-4.089 Y25.451 Z9.000
G1 X-4.482 Y25.705 Z9.000
G2 X-6.306 Y34.519 Z9.000 I3.448 J5.310 K0.000
G1 X1.071 Y44.823 Z9.000
G2 X-1.050 Y54.517 Z9.000 I5.258 J6.230 K0.000
G1 X7.314 Y71.337 Z9.000
G2 X12.675 Y71.359 Z9.000 I2.686 J-1.337 K0.000
G1 X15.866 Y65.078 Z9.000
G1 X15.866 Y65.078 Z3.000
G1 X21.332 Y54.319 Z3.000
G2 X20.383 Y46.240 Z3.000 I-6.561 J-3.324 K0.000
G2 X18.791 Y44.657 Z3.000 I-13.488 J11.966 K0.000
G1 X25.652 Y34.089 Z3.000
G2 X24.014 Y25.438 Z3.000 I-5.357 J-3.466 K0.000
G1 X30.607 Y15.209 Z3.000
G2 X26.098 Y6.938 Z3.000 I-4.518 J-2.902 K0.000
G1 X23.000 Y6.938 Z3.000
G1 X23.000 Y0.000 Z3.000
G2 X20.000 Y-3.000 Z3.000 I-3.000 J0.000 K0.000
G1 X0.000 Y-3.000 Z3.000

Appendix

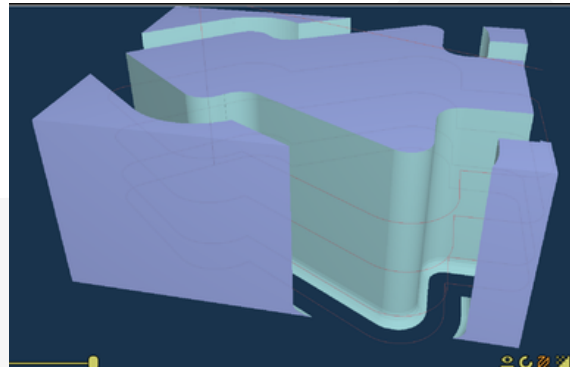
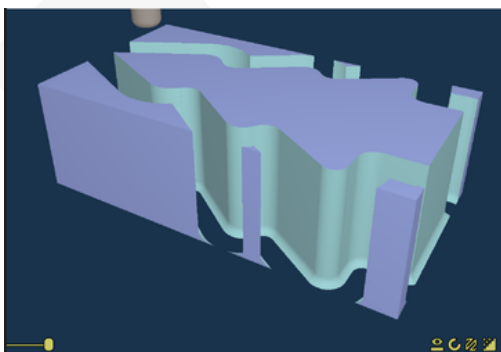
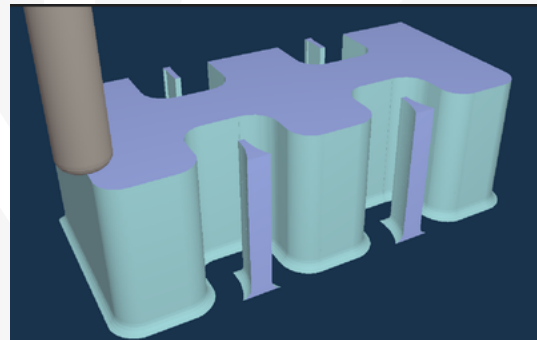
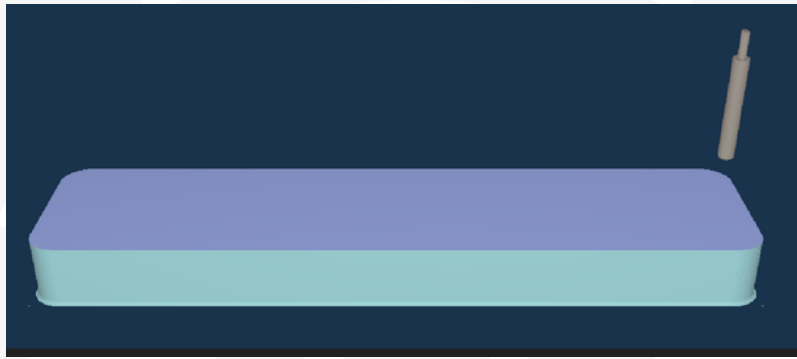
Student output: Fa_1 NC code (continued)

```
G2 X-3.000 Y0.000 Z3.000 I0.000 J3.000 K0.000
G1 X-3.000 Y7.000 Z3.000
G1 X-5.852 Y7.000 Z3.000
G2 X-10.413 Y15.153 Z3.000 I0.009 J5.357 K0.000
G1 X-4.089 Y25.451 Z3.000
G1 X-4.482 Y25.705 Z3.000
G2 X-6.306 Y34.519 Z3.000 I3.448 J5.310 K0.000
G1 X1.071 Y44.823 Z3.000
G2 X-1.050 Y54.517 Z3.000 I5.258 J6.230 K0.000
G1 X7.314 Y71.337 Z3.000
G2 X12.675 Y71.359 Z3.000 I2.686 J-1.337 K0.000
G1 X15.866 Y65.078 Z3.000
G1 X15.866 Y65.078 Z-1.000
G1 X21.332 Y54.319 Z-1.000
G2 X20.383 Y46.240 Z-1.000 I-6.561 J-3.324 K0.000
G2 X18.791 Y44.657 Z-1.000 I-13.488 J11.966 K0.000
G1 X25.652 Y34.089 Z-1.000
G2 X24.014 Y25.438 Z-1.000 I-5.357 J-3.466 K0.000
G1 X30.607 Y15.209 Z-1.000
G2 X26.098 Y6.938 Z-1.000 I-4.518 J-2.902 K0.000
G1 X23.000 Y6.938 Z-1.000
G1 X23.000 Y0.000 Z-1.000
G2 X20.000 Y-3.000 Z-1.000 I-3.000 J0.000 K0.000
G1 X0.000 Y-3.000 Z-1.000
G2 X-3.000 Y0.000 Z-1.000 I0.000 J3.000 K0.000
G1 X-3.000 Y7.000 Z-1.000
G1 X-5.852 Y7.000 Z-1.000
G2 X-10.413 Y15.153 Z-1.000 I0.009 J5.357 K0.000
G1 X-4.089 Y25.451 Z-1.000
G1 X-4.482 Y25.705 Z-1.000
G2 X-6.306 Y34.519 Z-1.000 I3.448 J5.310 K0.000
G1 X1.071 Y44.823 Z-1.000
G2 X-1.050 Y54.517 Z-1.000 I5.258 J6.230 K0.000
G1 X7.314 Y71.337 Z-1.000
G2 X12.675 Y71.359 Z-1.000 I2.686 J-1.337 K0.000
G1 X15.866 Y65.078 Z-1.000
G0 Z26.000
G0 Z26.000
(Finish operation: Profile)
(Begin postamble)
M5
G17 G90
M2
```


Appendix

Student output:

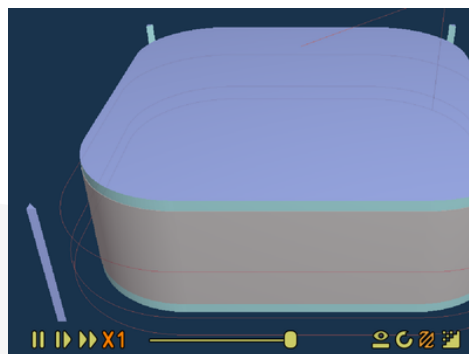
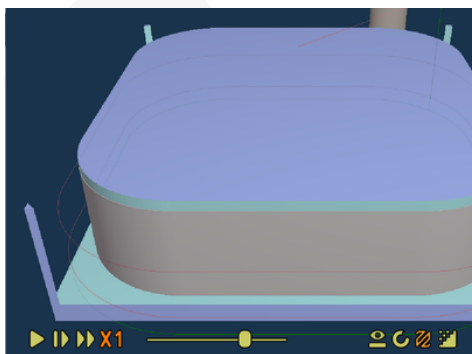
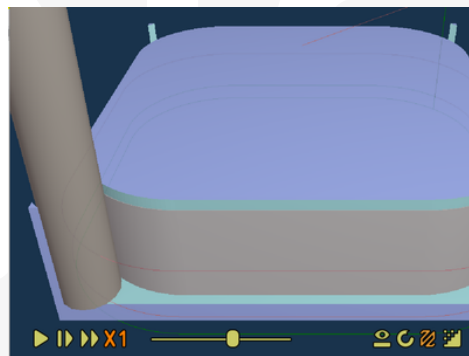
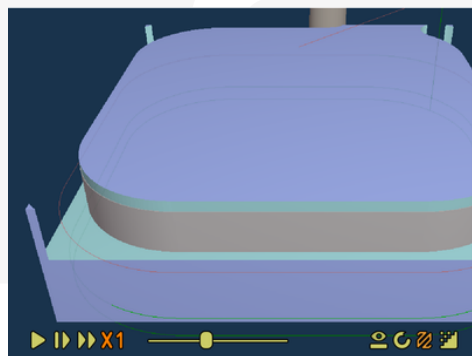
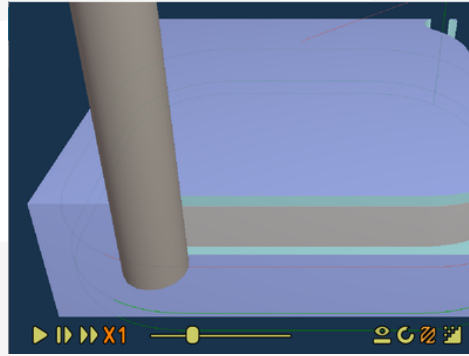
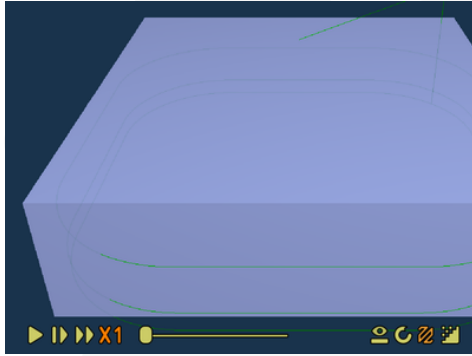
3D simulation images



Appendix

Student output:

- 3D simulation





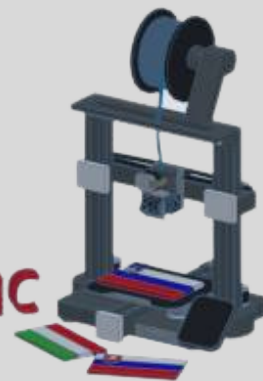
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CNC



**Spojená škola
Kollárova 17, Sečovce**

**SOLSKI CENTER
SLOVENJ GRADEC**



**Móricz Zsigmond
Református Kollégium,
Gimnázium, Technikum,
Általános Iskola és Óvoda**

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