Preliminary Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Automation Technology

Workgroup: University of Cagliari

University of Cassino and Southern Lazio

This document is the Preliminary Design Review of the technical competence 'Working with machinery and specialised equipment'. Its briefly contains the experimental platform analysed in MISCE project, to be designed and standardised for improving the acquisition level of this competence on engineering degrees.

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1 Competence and skills

This module focuses on developing practical and theoretical skills in the field of **Fused Deposition Modeling (FDM)** using the **Original Prusa MK4 3D printer**. Students will gain hands-on experience with the complete 3D printing workflow, from preparing digital models to operating and maintaining the machine.

Throughout the activities, learners will acquire essential competences that align with the requirements of modern digital fabrication environments, including troubleshooting, software use, and understanding mechanical and electronic components.

A1.3DP – Additive Manufacturing Technology

which related skills are (see Table I):

Table I. Skills

S1.1.	Prepare and calibrate the Prusa MK4 for a successful print
S1.2.	Import and process a 3D model using the slicing software (PrusaSlicer)
S1.3.	Execute a print operation to produce a functional or demonstrative component
S1.4.	Evaluate print quality and make necessary adjustments based on observed performance

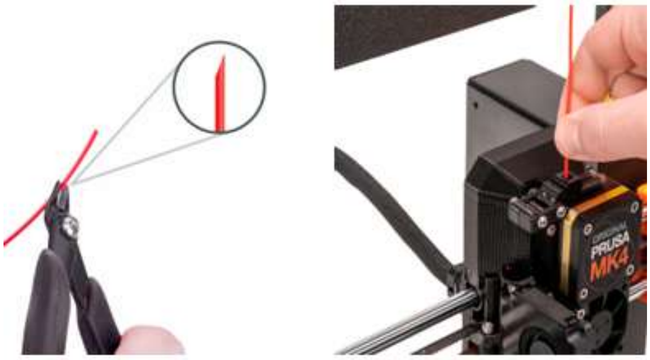
By the end of this unit, students will be able to operate a professional-grade 3D printer with confidence and competence, preparing them for further applications in prototyping, engineering, or product design.

2 Experimental proposals

In this chapter, students will become familiar with the basic tools and processes needed to use the Original Prusa MK4 3D printer. A hands-on experiment will guide them through the entire additive manufacturing workflow, from cutting the digital model to final object evaluation.

To support this learning path, Table II summarizes the key devices and software components used in the experiment.

Table II. Proposed devices for 'automation technology' competence

	
Prusa MK4 3D printer	PLA Filament
	
Test model	

In the following sections each device is detailed explained.

2.1 Prusa MK4 3D printer

This 3D printer has been widely adopted for educational and experimental purposes (e.g. [1-3]). The system in question is the PRUSA MK4 model, an FFF (Fused Filament Fabrication) printer featuring the next-generation "Nextruder," a magnetic heated bed, and a fully automated calibration system. Designed for high precision and reliability, the MK4 is also user-friendly for beginners thanks to its intuitive interface and simplified material handling (see Figure 1).

Figure 1. Prusa MK4 3D printer

In this proposal, we present the printing of a small 3D model of a ship as a concrete example of using 3D printing for prototyping and educational object creation. The model was designed with CAD software, prepared for printing using PrusaSlicer, and produced in PLA directly on the MK4 printer.

The main advantage of this platform lies in its versatility for educational use: it introduces students to modelling, rapid prototyping, and the fundamentals of digital manufacturing. Moreover, the reliability of the printing process and the quality of the final output provide an immediately rewarding and tangible learning experience.

On the downside, the main limitation is its technical nature, which requires a basic understanding of filament handling, slicing software, and error resolution, as it is nonetheless a sophisticated system.

2.2 PLA filament

The material used for printing the model is PLA (Polylactic Acid), one of the most common and education-friendly 3D printing filaments. It is a bioplastic derived from renewable sources such as corn starch and is known for its ease of use, low extrusion temperature (around 200–215 °C), and minimal warping during cooling. PLA emits little to no odor while printing, adheres well to untreated surfaces, and is available in a wide range of colours (see Figure 2).

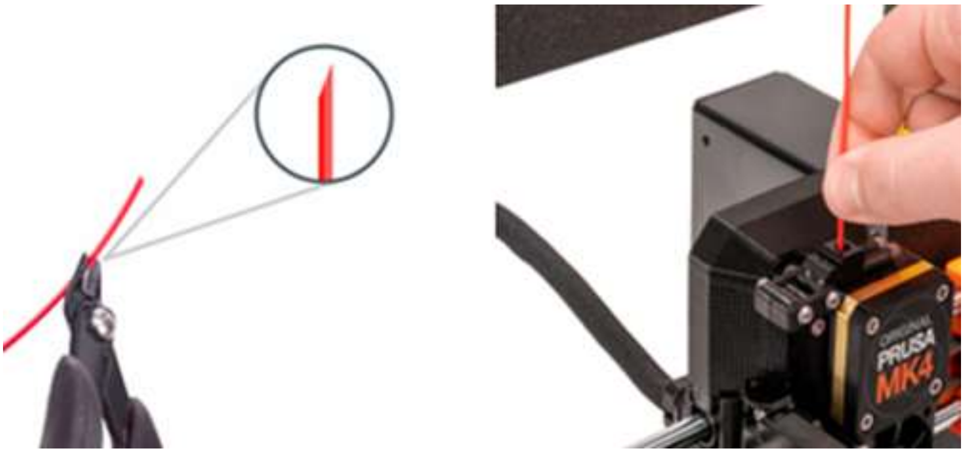


Figure 2. PLA filament

Thanks to these properties, PLA is especially suitable for educational models, conceptual prototypes, and decorative objects. It is the recommended material for beginners in 3D printing, as it allows for accurate results with minimal risk of print failure.
Its main drawback is its low heat resistance and poor weather durability, which make it unsuitable for functional or outdoor applications.

2.3 Test model

One of the most iconic tests for evaluating 3D printer performance is printing the "3DBenchy" model—a small boat specifically designed to challenge a printer's precision, detail handling, and overall print quality. This model is often used in educational settings as a hands-on introduction to 3D printing, as it incorporates many typical challenges of FFF printing in a single object (see Figure 3).

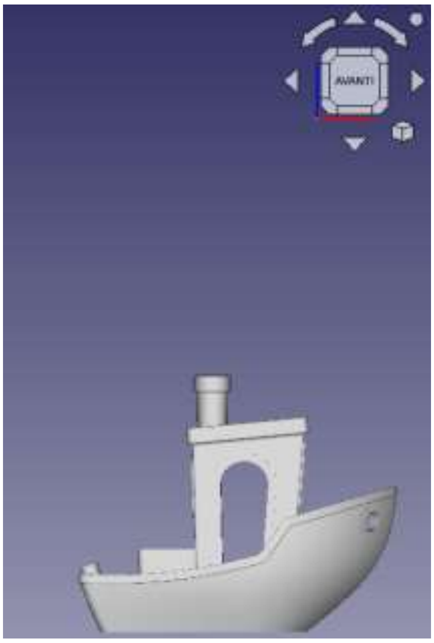


Figure 3. 3D model of 3DBenchy designed for printer testing

The digital file for the 3DBenchy was processed using **PrusaSlicer** software (e.g. [4]), where key parameters such as layer height, nozzle temperature, and infill percentage were configured. The slicing process converts the model into a G-code file that can be read by the printer (see Figure 4).

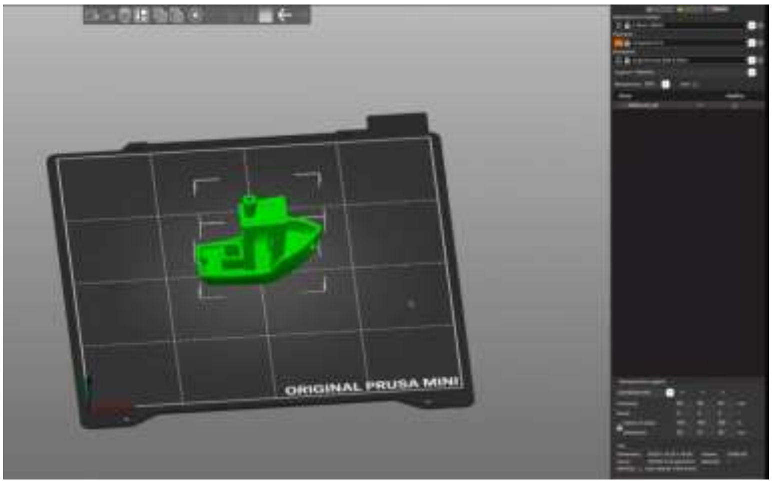


Figure 4 Model preview in the PrusaSlicer slicing software

The final print was executed with the Original Prusa MK4 using red PLA filament, completed in approximately 2 hours and 30 minutes. The resulting object is well-finished and showcases the printer's capability in dimensional accuracy and surface quality (see Figure 5).

Figure 5 3DBenchy model printed in PLA with the Prusa MK4

3 Competence and skills analyses

The learning unit developed in this work focuses on additive manufacturing through the use of a desktop FFF 3D printer (Original Prusa MK4), and integrates both software and hardware-based tasks. The objective is to provide students with a **complete educational experience**, from digital model creation to physical object realization.

As defined in **Table I**, the activity targets four key competences related to digital manufacturing:

- **S1.1** – Preparation and calibration of the 3D printer (Prusa MK4)
- **S1.2** – Import and processing of a 3D model using slicing software (PrusaSlicer)
- **S1.3** – Execution of the print operation
- **S1.4** – Evaluation of print quality and optimization through iterative adjustments

These skills reflect essential phases of the digital fabrication workflow and are directly addressed through the sequence of steps performed during the educational activity: modeling, slicing, printing, and result analysis.

Table III provides a synthesis of the contribution that each phase of the 3D printing workflow makes to the development of these competences. The table compares three core components of the workflow—modeling, slicing, and physical printing—against the skills defined in Table I, using a five-star scale for evaluation.

This structured analysis highlights the **complementarity** between digital design and physical execution, showing how each stage supports specific technical skills. The overall assessment confirms that this activity is highly effective in developing practical competences in digital manufacturing environments.

Table III. Contribution of the 3D printing activity to digital manufacturing competence and related skills

Platform	S1.1	S1.2	S1.3	S1.4	**Overall competence contribution**
3D Modeling (FreeCAD)	★★☆☆☆ Strong skill in digital modeling, limited hardware interaction	★★★★★ Strong skill in digital design and preparation of files for slicing	★☆☆☆☆ Limited contribution to physical execution	★★☆☆☆ Basic understanding of outcome vs. model	★★★☆☆ 3.0
Slicing (PrusaSlicer)	★★★☆☆ Ability to prepare the printer configuration for fabrication	★★★★☆ Skill in processing files and adapting print parameters	★★☆☆☆ Moderate interaction with print execution	★★★★☆ Key role in evaluating layer structure and infill setup	★★★½☆ 3.75
Physical Printing (Prusa MK4)	★★★★★ Hands-on interaction with hardware and calibration tools	★★☆☆☆ Some interaction with print files and formats	★★★★★ Direct involvement in print execution and process monitoring	★★★★★ Effective analysis of defects and machine behavior	★★★★☆ 4.25

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