3D PRINTING TECHNOLOGY

SHIFTVET

Digital Transformation for
Wood and Furniture VET

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Key terms

CAD (Computer-Aided Design)
Software used to design three-dimensional digital models that can later be printed.

STL (STereoLithography)
Standard file format for 3D printing that represents the geometry of a 3D object. It does not contain color or material information.

OBJ / 3MF
Alternative 3D file formats to STL. Like STL, they are commonly used for 3D printing preparation.

Slicer / Slicing software
Software that converts a 3D model (STL, OBJ, 3MF) into printable instructions by dividing it into layers and defining printing parameters.

G-code
Machine instruction language generated by the slicer. It tells the 3D printer how to move, what temperature to use, and how to build each layer.

FDM (Fused Deposition Modelling)
3D printing technology that melts and deposits plastic filament layer by layer. Most common in educational environments.

SLA (Stereolithography)
3D printing technology that uses light to cure liquid resin layer by layer, producing high-detail prints.

SLS (Selective Laser Sintering)
Industrial 3D printing technology that uses a laser to fuse powdered material into solid parts.

PLA (Polylactic Acid)
A biodegradable, easy-to-print plastic commonly used in education.

PETG (Polyethylene Terephthalate Glycol)
A more resistant and flexible plastic filament than PLA.

PPE (Personal Protective Equipment)
Safety equipment such as gloves, goggles, or respirators used when operating printers.

VOC (Volatile Organic Compounds)
Gases that may be emitted during printing, especially relevant for ventilation considerations.

1. Introduction

1.1 ShiftVET Project Overview

The **ShiftVET Project** is designed to support initial Vocational Education and Training (i-VET) trainers in introducing digital technologies into carpentry teaching. Its aim is to help modernize current training programs so that students can develop the digital skills needed in the carpentry and manufacturing industries. By making learning more innovative and engaging, the project also aims to increase students' interest in these career paths.

To guide this transformation, **ShiftVET** focuses on four key objectives:

- Help trainers understand how digital technologies can be applied in carpentry VET and how they can improve teaching and learning.
- Create a free online repository of accessible materials, examples, and exercises that teachers can easily integrate into their classes.
- Test practical digital tools, such as 3D printing, with students to explore how these technologies can enhance hands-on learning.
- Encourage the use of advanced technologies not only among project partners but also in other vocational training centers while exploring how the tools could benefit other industries.

1.2 Purpose of this guide

The aim of this guide is to help VET training instructors in carpentry to introduce and integrate **3D printing** into their teaching practice. As digital technologies increasingly shape the carpentry and manufacturing sectors, 3D printing has become a powerful tool for design, prototyping and creative problem solving. Understanding its potential is essential to preparing students to thrive in their modern, technology-enabled professional environment.

This guide has been specifically developed to help educators gain the knowledge, confidence and practical skills necessary to effectively use 3D printing in woodworking instruction.

It offers a clear and accessible introduction to the fundamentals of additive manufacturing: what it is, how it works and why it is an important complement to traditional woodworking techniques.

More specifically, this guide aims to:

- Build a solid foundation on the principles of 3D printing, including key concepts, materials, machine types and essential digital workflows.
- Clarify its relevance to woodworking, showing how 3D printing can support activities such as prototyping, custom tool making, joint experimentation, design validation and complex shape development, among other activities.
- Provide practical, classroom-ready strategies for incorporating 3D printing into VET programs, including lesson ideas, exercises, safety considerations and tips for managing printers.
- Support trainers with varying levels of experience by offering explanations and examples that make technology accessible even to those who are new to it.
- Strengthen the links between digital and traditional craftsmanship, helping students understand how 3D printing can complement woodworking techniques rather than replace them.

Ultimately, the purpose of this guide is to make 3D printing an accessible, inspiring, and educationally valuable resource for both trainers and students, helping them bridge the gap between traditional craftsmanship and the opportunities of the digital age.

1.3 Who is the guide aimed at?

This guide is designed for vocational training instructors and educators in carpentry who wish to introduce 3D printing into their teaching practice. It is aimed at professionals who may have varying levels of familiarity with digital technologies, from those who are just starting out to those who are more experienced and want to integrate it more effectively into their classes.

More specifically, this guide is aimed at:

- Vocational training instructors in carpentry are looking for practical tools, examples and strategies for incorporating 3D printing into their classrooms and workshops.
- Vocational training providers and training centers are interested in modernizing their curricula and offering students access to relevant digital technologies.

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- **Educators in related technical or manufacturing fields** who want to understand how 3D printing can complement traditional craftsmanship and enhance learning experiences.
- **Trainers in continuing professional development** want to strengthen their digital skills and expand their teaching resources.
- **Anyone involved in designing, coordinating or supporting vocational training programs** that aim to promote innovation, creativity and digital readiness among students.

1.4 How to use this guide?

This guide is designed as a practical and flexible resource to help trainers integrate 3D printing into vocational training in carpentry.

You can use it progressively, returning to different sections as your understanding and confidence grow. There is no need to read it all at once; instead, it can accompany you throughout your teaching practice.

Here's how to get the most out of it:

1. **Start with the basics**- Begin by exploring the introductory chapters to understand what 3D printing is, how it works, and why it is becoming increasingly relevant in woodworking. This foundation will help you connect technology with traditional training methods.
2. **Familiarize yourself with the tools and materials**- Review the sections describing the types of 3D printers, common materials, software workflows, and essential terminology.
3. **Explore pedagogical applications**- The guide includes examples and explanations illustrating how 3D printing can be applied in woodworking vocational training. These sections will help you visualize opportunities in the classroom.
4. **Use the hands-on activities**- You will find demonstrations for the classroom. These activities are designed to be flexible so they can be adapted to different levels.
5. **Experiment and reflection with your students**- Implementation is most effective when trainers and students explore the technology together. Use hands-on tasks to experiment, discuss results, solve problems, and encourage students to improve their designs.

6. Use it as an ongoing reference- The guide is not meant to be read once and set aside. It is a reference you can turn to whenever you need clarification, examples, or inspiration for designing new lessons. You can also combine them with the following resources that will be developed in the ShiftVET project.

2. Description of technology

2.1 What is 3D printing?

3D printing is the process of creating objects by depositing layers of material on top of each other.

This technology has been around for a long time, since it was invented in the early 1980s, and has advanced technologically over the years. Today, it is one of the most widely used technologies for manufacturing processes, as it is more affordable and faster than before.

Computer-Aided Design (CAD) is used for 3D printing with the aim of creating three-dimensional objects through stratification.

The creation of this object is therefore achieved through additive processes, placing layer upon layer [1].

3D printing has three characteristics to consider:

- These are manufacturing processes that involve adding material to build a solid three-dimensional object.
- The object is built by superimposing successive layers of material.
- The object is manufactured from a digital 3D model.

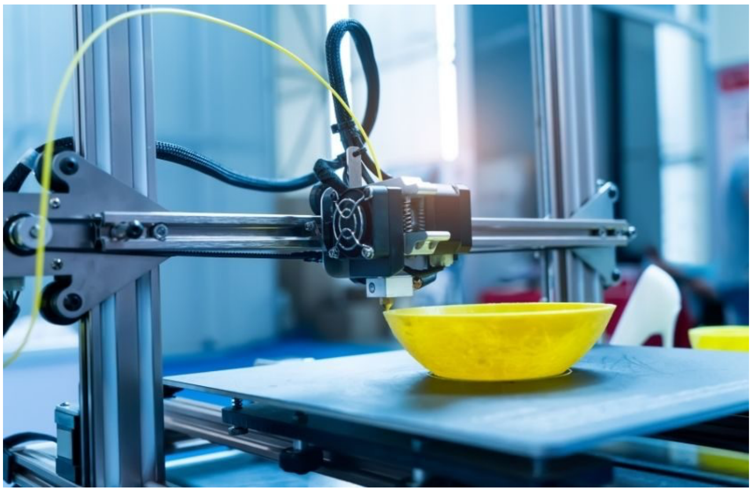

Figure 1: 3D printing [2].

2.2 How does 3D printing works?

3D printing is a different way of producing parts compared to other technologies. The 3D printing process always begins with a digital 3D model as a blueprint for the physical object. The printer software then slices this model into thin two-dimensional layers and converts it into a set of machine language instructions that the printer can execute.

After this step, the process may vary depending on the printer model. In the case of desktop FDM printers, they melt plastic filaments and deposit them on a printing platform through a nozzle.

In the case of large industrial machines such as SLS, they use lasers to melt thin layers of material.

The materials used to create the object also vary depending on the process. Plastics are the most common, but other materials such as metals can also be used.

Depending on the size of the part being created, the process can take between 4 and 18 hours, approximately.

But the process does not end there, as the part can rarely be used straight out of the printer. They usually need some kind of processing to achieve the desired surface finish, and this often requires more time and effort, usually manual.

Figure 2: FDM printer [3]

Figure 3: SLS printer [4]

To see it in more detail and understand it better, we will look at the process of creating a piece with a 3D printer step by step.

First step- Create the content:
The first thing to do is to create a three-dimensional digital file of the object we are going to print. The most common way to do this is to create a computer-aided design (CAD), but there are other software options that can produce the file as well.
This can be done using design software such as Blender, SketchUp, AutoCAD, SolidWorks, Maya, Photoshop, Thinker CAD, among others. It can also be done using 3D scanning, if available. Or Another way is to download ready-made, open-source files for 3D printing.
Step two- Convert the design to STL format:
Once the design is finished, it's time to send it to the printer. The first thing we need to do is convert it to a format that is compatible with the machine.
The format used for 3D printing is called STL (*STereoLithography)*. This file is the correct one for the next step.
It is important to note that STL, .OBJ, and .3MF, which are alternatives to STL, do not contain color information, so if you want to print in color you will need to use file formats such as .X3D, WRL, DAE, or PLY.
Step three- Slicing:
This step is where we translate the 3D file into instructions for the printer to follow. To do this, we need special software.
This step basically consists of dividing or cutting the 3D model into many horizontal layers, telling the machine exactly what to do.
After slicing the files, a new file format called G-code will be generated. This is the most widely used numerical code programming language for controlling automated machine tools such as 3D printers.
In short, G-code is the machine language we will use to communicate with the machine and give it instructions.
Step four- Printing:
Printing machines are made up of many parts and require proper maintenance and calibration to ensure that the part is printed correctly.
Most printer models do not need to be supervised while the part is being created, as the machine follows automated G-code instructions, so unless there is a software error or the machine runs out of filament, there will be no problems.

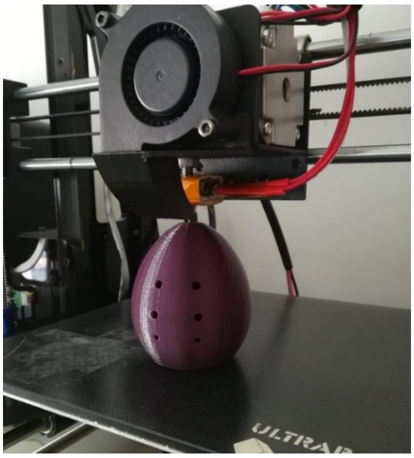

Figure 4: Piece being printed [5].

Step five- Remove the part from the printer:

This step varies depending on the different 3D printing technologies. In some cases, such as with desktop machines, it is as simple as separating the object from the build platform.

In other cases, such as industrial printers, removal is a somewhat more technical process that requires professional skills.

Step Six- Post-processing:

This final step will also vary depending on the 3D printing technologies and materials used for printing.

Some technologies allow us to manipulate the piece immediately, but others require a few extra steps for the aesthetics and function of the object.

Some parts tend to have a rough texture, but this can be improved with craft processes such as sanding, polishing, or other methods.

On the other hand, when it is not aesthetics but mechanical properties that are important, post-processing can be more complicated and require more technical skills [1].

Figure 5: Figure before and after finishing it [6]

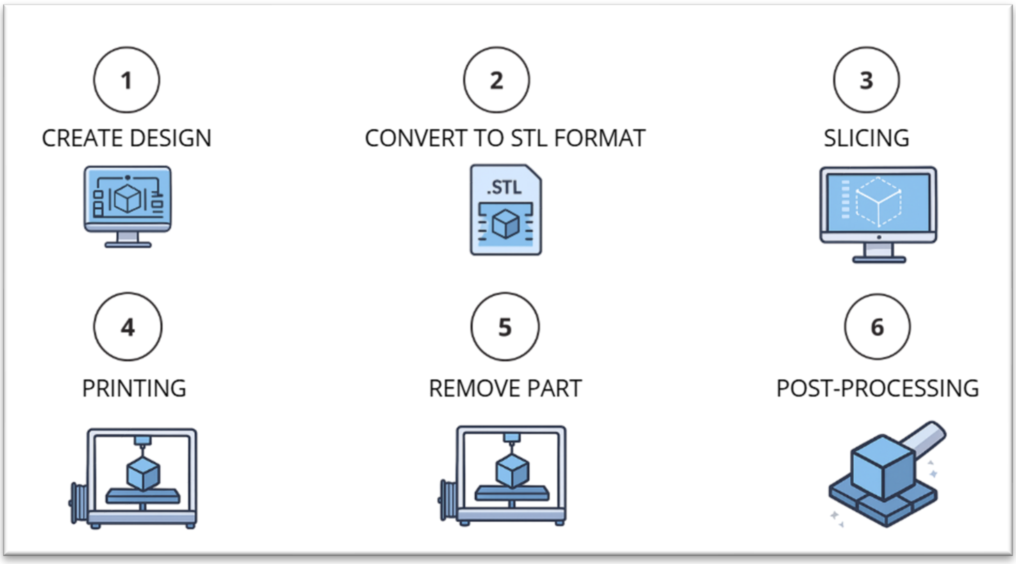

Figure 6: Steps of 3D printing. Open IA (2025)

2.3 Types of 3D printing technologies

There are different technologies available for 3D printing, but the most common ones are listed below:

FDM 3D printing

This is **the most widely** used among consumers and the most recognizable for people who do not have much knowledge on the subject.
FDM 3D printers are most found in classrooms, educational workshops, and makerspaces, where they are used as an introduction to the world of digital

manufacturing. In professional environments, they are mainly used for proof-of-concept models, allowing ideas to be validated before manufacturing more advanced prototypes.

Their popularity is due to their ease of use and affordable price, which lowers the barrier to entry for those new to the world of 3D printing. It is true that this technology often sacrifices surface quality or mechanical strength as it is not designed for superior performance

SLA 3D printing

Stereolithography (SLA) 3D printing was the world's first 3D printing technology, but it has taken longer than the previous one to be accepted and gain the recognition it deserves, as it tends to be more expensive and the printing process is somewhat more complicated for those who are not very familiar with it.

This printing technology is a process where a light source cures liquid resin, hardening it layer by layer. Previously, the light was a laser, but recently it has been replaced by a digital light projector.

These printers produce parts with smoother finishes, tighter tolerances, and greater dimensional accuracy. They are ideal for functional prototyping and for creating end-use products because they have excellent finish.

3D SLS Printing

Selective laser sintering (SLS) is the most common additive manufacturing technology for industrial applications. Engineers and manufacturers in many sectors use it for its ability to produce strong, functional parts.

These printers typically use a high-power laser to melt small particles of polymer powder. The unmelted powder serves as a support for the part during printing and eliminates the need for support structures.

Parts produced using SLS have very interesting mechanical characteristics, with a strength like that of injection-molded parts. The most common material used is nylon (thermoplastic) as it is lightweight, strong, and flexible [7].

2.4 General applications

In addition to the wood sector, it is important to consider the wide variety of uses offered by 3D printing, as its benefits extend to numerous industrial, educational, and creative fields. This technology allows for process optimization, cost reduction, and innovation in multiple disciplines.

One of the most notable applications is rapid prototyping, which allows designers, engineers, and students to create physical models of their designs in a very short time. This makes it possible to test functionalities, detect errors, evaluate proportions, and improve the product before moving on to a more costly manufacturing phase. This reduces risks and shortens development cycles.

3D printing is also essential for the manufacture of customized parts. In sectors such as medicine and dentistry, it is used to create prostheses, splints, implants, or anatomical models adapted to the unique characteristics of each patient. In fields such as engineering, fashion, or sports, it allows for the development of products tailored to specific measurements, facilitating ergonomics and comfort.

Another relevant application is the creation of customized industrial tools, fixtures, and accessories. Many companies print supports, guides, templates, adapters, or machine parts, improving process accuracy and reducing work times. This customization allows for immediate solutions without relying on external suppliers or long manufacturing times.

3D printing is also a very efficient option for small series production. When few units, customized products, or experimental runs need to be manufactured, this technology is more economical than traditional methods, which require molds or specialized machinery. For this reason, it has gained ground in sectors such as product design, jewelry, architecture and personalized consumer goods.

The technology is also valuable for repair and maintenance work. The ability to print specific parts on demand avoids the need to store large inventories or discard machinery due to the lack of a hard-to-find component. This contributes to sustainability and reduces replacement costs.

Finally, 3D printing is also used in areas such as education, to support hands-on learning and the development of STEM skills; in research and material creation; in architecture, to model buildings and furniture; and even in the art industry, where it allows for the production of sculptures, decorative elements, and complex reproductions [8].

2.5 Required equipment

The implementation of this technology in educational centers require the correct selection of equipment and materials to ensure correct, efficient, and appropriate use for VET educational needs. Below are some essential recommendations for getting started with this technology. Since this guide focuses on the VET educational environment, we will focus on the recommended equipment needed for educational centers.

A. **FDM (Fused Deposition Modelling) printers** are the most common technology in education because they are simple, affordable, and easy to learn how to use. According to *Formlabs*, FDM printers continue to be the most common type because:
   - They have intuitive processes that are suitable for teachers and students who are new to this technology.
   - They offer an accessible learning curve, as you can clearly see the layers of manufacturing.
   - They are priced within a range that is suitable for institutions, as they typically cost between €850-€3,450.

Below is a series of basic **recommendations** for centers to integrate this technology into the classroom:

- Minimum print areas of 200 x 200 x 200 mm (The print area is the space inside the printer where objects are created)
- Heated base (It is the surface on which the piece rests during printing)
- Automatic or assisted levelling (To print properly, the printer needs the base to be perfectly level)
- Filament sensor (The filament is the "material" used by the machine to print, like a plastic thread. The sensor alerts you when the spool is about to run out, pauses printing if the filament breaks, and prevents the loss of long pieces due to lack of material)
- Closed or semi-rigid enclosure, for added safety (A closed-cab printer has a "box" around the printing area).
- Accessible slicing software (Cura, PrusaSlicer, etc.)
- Simple maintenance and affordable replacement parts (Clean the nozzle, change belts or wheels or replace the print bed if it wears out)

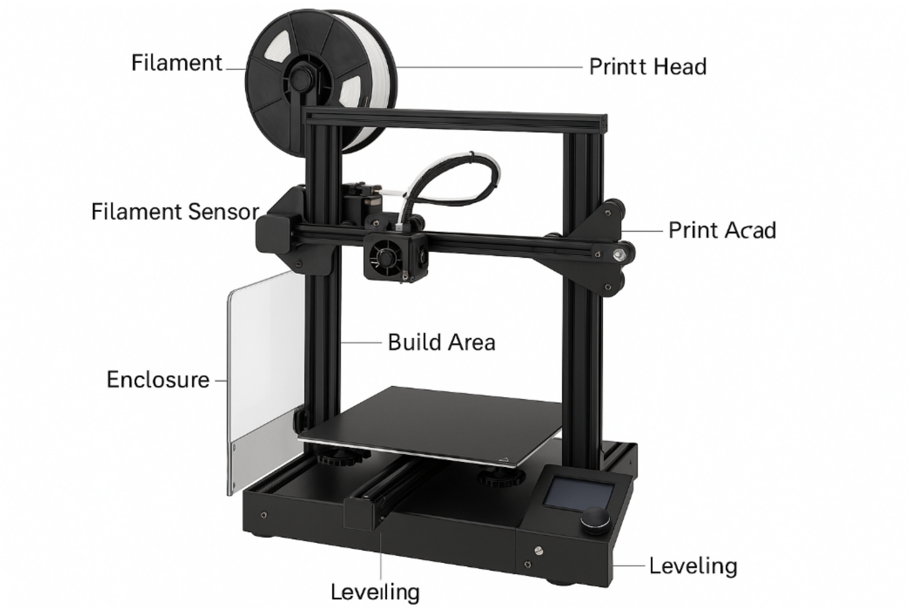

Figure 7: Parts of a FDM 3D printer machine. Open IA (2025).

B. Materials.

The choice of material also influences the quality, strength, and aesthetics of the piece. Among the most recommended materials available for use in VET courses are:

- PLA (Polylactic Acid)- This is the most common material due to its ease of printing, dimensional stability, safety, and good finish.
- PETG (Polyethylene Terephthalate Glycolate)- This material is somewhat more resistant and flexible.
- Filaments used with wood- There are also filaments of this type, made from a mixture of PLA and real wood fibers [9].

Material	Advantages	Limitations	Typical VET use
PLA (Polylactic Acid)	Easy to print, low warping, good surface finish, biodegradable, low emission of fumes	Lower mechanical strength, less heat resistant	Ideal for beginners, prototypes, decorative elements, basic tools

PETG (Polyethylene Terephthalate Glycol)	More resistant and flexible than PLA, good layer adhesion, moisture resistant	Slightly harder to print, can produce stringing	Functional parts, workshop accessories, elements exposed to moderate stress
ABS (Acrylonitrile Butadiene Styrene)	High strength and heat resistance	Requires high temperatures, enclosed printer, produces fumes, prone to warping	Advanced use only; generally, not recommended for classrooms

C. Software

To work with 3D printing, you need to use two main types of software: one for modelling what you want to print in 3D and another for preparing and converting the model into instructions that the printer can understand.

Modelling software: CAD (Computer-Aided Design) allows you to create digital three-dimensional models that can then be exported for printing. Some of the recommended software for beginners are:

- Tinkercad (beginner level)
- Fusion 360 (intermediate-advanced level)
- FreeCAD (completely free software)

Slicers: The slicer converts the 3D model we have created into a file that the printer understands, usually G-code. Some examples are:

- Ultimaker Cura (the most common), free and compatible with almost all FDM printer models.
- PrusaSlicer, also free, which allows for more detailed control of the technical parts

Minimum technical requirements: For CAD and slicer programs to work, it is recommended that the center's computers meet the following requirements:

- **Computer (PC or laptop) - Processor:** Intel i5 or equivalent, **RAM:** minimum 8 GB (ideally 16 GB for Fusion 360), **Graphics card:** integrated sufficient for Tinkercad and FreeCAD; dedicated recommended for Fusion 360. **Storage:** 10–20 GB free and **operating system:** Windows 10/11, macOS, or Linux (only some programs).
- **Internet connection**
- **For 3D printing -** USB port, SD card reader or Wi-Fi connection (depending on printer model) and disk space to manage STL and G-Code files [10].

2.6 Typical beginner mistakes to avoid

In 3D printing, beginners often make mistakes that result in quality issues, wasted material, or failed prints if not addressed from the outset. Among the most common mistakes are failing to level the bed correctly or misadjusting the Z-axis height, which compromises the adhesion of the first layer; using inappropriate temperatures for the chosen material or printing at excessive speeds, which causes defects such as stringing or poorly fused layers; and failing to adapt the slicer settings to each model or filament, which can lead to under-extrusion or deformation. Avoiding these basic errors from the outset saves time, frustration, and material, and significantly improves the quality of the results.

2.7 Technical Setup Checklist

Before starting any classroom activity with 3D printing, it is essential to make sure that the equipment is properly set up and safe to use. The following checklist summarizes the key technical elements that teachers should verify before printing. Use it as a quick-reference tool to ensure reliability, safety, and smooth operation of the printer.

Equipment readiness

- ☐ The printer is installed in a stable, ventilated, and safe area.
- ☐ The build plate is clean and correctly levelled (manual or assisted).
- ☐ The filament spool is properly loaded, and the printer detects it.
- ☐ Nozzle and extruder are free from dust, burnt filament, or obstructions.
- ☐ You have enough filament for the entire print.
- ☐ The slicing software is updated and compatible with your printer.

- ☐ STL files are exported correctly and do not show mesh errors.
- ☐ The G-code has been reviewed (layer height, supports, infill, temperatures).

Safety checks

- ☐ Students have been informed about hot surfaces.
- ☐ No loose clothing or long hair is near the machine.
- ☐ Fire-safe materials and PPE are available if required.
- ☐ Clear instructions are given on what students can/cannot touch during printing.

Digital resources

- ☐ You have access to CAD software for last-minute adjustments.
- ☐ Models from external sources have appropriate licenses for classroom use.

3. Potential of technology in woodworking VET

3.1 Educational benefits

The integration of 3D printing into vocational training has many educational advantages that enrich learning. This technology facilitates the understanding of some more abstract concepts, but also promotes key skills for students' professional future, as the sector is becoming increasingly digitized in many aspects.

Hands-on learning:

One of the main advantages is that 3D printing transforms traditional learning, which is focused on theory and memorization, into a more dynamic process. Students will be able to design and manufacture their own creations, which generates a real connection with the subject matter. This makes students more motivated and increases classroom participation.

This approach is particularly effective in woodworking and carpentry VET programs, where experimentation and prototyping are part of the design and manufacturing process.

Development of critical thinking:

In addition, 3D printing also enhances cognitive skills such as identifying design errors, analyzing failures and improving prototypes and parameter adjustments to optimize results.

It is a fact that hands-on learning allows students to detect problems more quickly, which fosters an analytical and solution-oriented mindset.

Preparation for future jobs:

Looking ahead, the use of 3D printing in the classroom helps students acquire digital skills that are aligned with the growing needs of the sector. Students use these technologies during their training to feel more prepared for real-world tasks that will arise in their professional lives.

In woodworking VET courses, these skills can translate into greater autonomy in developing parts, models, and tools, a skill that can be really useful in present and future working life.

Collaborative work:

This technology also encourages collaboration among students in the classroom as it promotes communication, coordination, and knowledge sharing between different disciplines such as fashion, engineering, design, art... It is not only applicable to one sector but is a versatile technology that can be adapted to many.

Encouraging creativity:

Having the ability to transform your own ideas into real objects boosts students' creativity.

Some testimonials from students at the public high school in Dorchester, Massachusetts, where *Formlabs* and *TechBoston Academy* held a 3D printing course, reveal that thanks to access to 3D printers in the classroom, they were able to develop innovative ideas, real prototypes, and complex projects that they would not have been able to develop using traditional methods. They say that this technology gave them the freedom to experiment [9].

3.2 Technical advantages of 3D printing in Vocational Training for woodworking and carpentry

More specifically in the woodworking sector, implementing 3D printing technology can bring numerous advantages. Integrating this technology into your projects can broaden creative horizons and optimize work.

3D printing allows you to create designs in your carpentry projects, giving you the ability to create custom pieces with complex patterns that cannot be achieved manually.

Figure 8: The 'Cocoon' lamp by HagenHinderdael, made using 3D printing [11].

3D printing also allows for improved precision and detail in wood creations. Using this technology guarantees refined finishes that elevate the quality of your projects.

In addition, this technology optimizes the use of materials in your workshop by reducing waste and precisely controlling the amount of material you will need for each component.

It is true that creating a piece of woodwork involves delicate craftsmanship and a lot of time, so in some cases, applying this technology can be very useful.

3D printing is not a substitute for craftsmanship, as this is a highly valuable art that we want to preserve, but it can sometimes be a useful tool because creating a piece with a printer reduces costs and speeds up the manufacturing process and as mentioned above, minimizes raw material waste [12], [13].

3.3 Pedagogical checklist

Introducing 3D printing in VET woodworking is not only a technical task, but also a pedagogical opportunity. Before designing classroom activities, teachers should verify that learning objectives, student readiness and curriculum alignment are clear. This checklist helps ensure that 3D printing is used in a meaningful, motivating and educationally effective way.

Learning goals

- ☐ The activity aligns with the woodworking curriculum.
- ☐ Students understand the difference between CAD, slicing, and printing.
- ☐ The task reinforces critical thinking (problem detection and improvement).
- ☐ The activity includes opportunities for hands-on learning.

Pedagogical preparation

- ☐ You have printed an example of the final piece to show the class.
- ☐ You have identified potential errors students may encounter (warping, support failure, etc.).
- ☐ You have prepared guiding questions (e.g., *Why did this layer fail? How can we fix it?*).
- ☐ You have planned moments for peer collaboration and group discussion.

Material adaptation for woodworking

- ☐ The printed model connects to real woodworking processes (joint prototypes, tooling aids, fixtures, decorative elements...).
- ☐ Students can compare digital prototypes with real wooden components.
- ☐ You have examples that show how 3D printing complements craftsmanship—not replaces it.

3.4 Example of activities for woodworking VET

To help teachers visualize how 3D printing can be integrated into woodworking training, the following examples present ready-to-use activities that can be adapted to different levels and workshop needs. These activities show how additive manufacturing can support learning, prototyping, tool making and experimentation in carpentry.

Short project-Beginner level (1–2 sessions): Printing a simple woodworking tool (stop block, spacer, jig accessory)

- Objective: Introduce students to the 3D printing workflow using a functional but simple object for the workshop.
- Description: Students download or create a basic model such as a cutting stop, a drilling guide, or a spacer block. They slice the model, print it, and test it in the woodworking workshop.
- Learning outcomes: Understand STL/G-code workflow; Observe tolerances and accuracy; Connect 3D printed objects with real workshop use
- Variation: Students modify the design to fit a specific machine or measurement.

Medium project – Intermediate level (3–4 sessions): Designing and prototyping a complex joint (e.g., dovetail joint, finger joint, mortise-tenon with special geometry)

Objective: Explore joinery through digital design and iterative prototyping.

- Description: Students design a wood joint in CAD, print a scaled version, evaluate fit, adjust tolerances, and finally create the joint in real wood. This allows them to understand angles, clearances and the mechanical behavior of joints before cutting expensive material.
- Learning outcomes: Develop CAD design skills; Analyze fit and mechanical behavior; Reduce material waste in the workshop
- Variation: Students compare multiple joint designs and present which one performs best.

Longer project- Advanced level (1–2 weeks): Designing a hybrid object combining wood + 3D printed parts (e.g., a lamp, small shelf, handle, hinge, decorative panel)

- Objective: Combine traditional craftsmanship with digital fabrication.
- Description: Students create an object in which wooden elements are complemented by 3D printed components. For example, a lamp where the

structure is wooden and the shade is 3D printed; a jig for the workshop; or a decorative pattern that cannot be easily carved by hand.

- Learning outcomes: Understand the complementary role of additive manufacturing; Plan assembly between two different materials; Apply both digital and traditional skills in one project
- Variation: Students document the entire process (design → printing → woodworking → assembly).

4. Integration in the classroom

4.1 Methodological recommendations

The incorporation of 3D printing in the classroom should be done **gradually**, as it is best to start with something simple and move forward step by step to fully understand how this technology works.

According to *Miaulatec*, 3D printing works best when you start with very **basic activities** such as printing existing models or simple parts. This helps students understand the entire process, and **working in stages**, dividing the project into small tasks, will help students fully grasp the workflow involved in creating a 3D piece.

Other important sources such as *Formlabs* emphasize that 3D printing favors practical learning methodologies and **project-based learning (PBL)**. By being able to manipulate physical objects, students better understand concepts and become more engaged in the classroom. It is also very important to know the classroom's level of proficiency with this technology so that the instructor can adapt and create tasks appropriate to the students' level, starting with simple things and later tackling more complex projects.

Before implementing this technology in the classroom, it is important that **teachers** are well **trained** in how it works so that they can support students and teach lessons on it correctly.

In summary, we would see that the most important things to implement this technology on the classroom:

- To start with simple practical projects
- Establish progressive tasks to advance little by little through trial and error
- Encourage other skills related to this technology such as creativity, teamwork, or critical thinking to see the mistakes made and how to solve them
- Accompany students throughout the process
- Train them on the responsible use of equipment and materials

[14], [15], [16].

One of the main challenges when integrating 3D printing into VET classes is managing printing times, as some prints may take several hours. To address this, teachers can apply the following strategies:

- Plan prints that can be completed within a single session for beginner activities.
- Use pre-printed examples when introducing new concepts, allowing students to focus on analysis and discussion.
- Schedule long prints outside teaching hours or between sessions.
- Divide the class into roles (design, slicing, monitoring, documentation) to keep all students engaged.
- Encourage students to estimate printing time and reflect on efficiency and optimization.

Effective time management ensures that 3D printing remains a supportive learning tool rather than a logistical obstacle.

4.2 Step-by-step implementation plan

Step 1- Prepare the environment and equipment

Before you start using this technology, it is important to install and configure the printer in a suitable space that is well ventilated and accessible.

It is advisable to start with test prints to check the levelling of the base, check the extruder, and ensure you have basic materials such as PLA (filament).

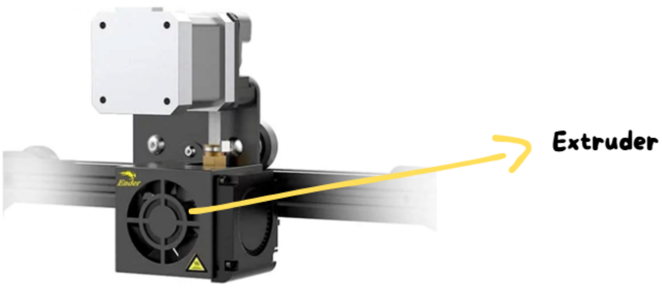

Figure 9: Extruder of a 3D printer [17].

Step 2- Initial teacher training

Before working with students, trainers must be familiar with the basic operation of the equipment: loading filament, starting and stopping prints, using the laminating software, and recognizing common faults.

With trained teachers, classes will run more smoothly, and student learning will be more positive.

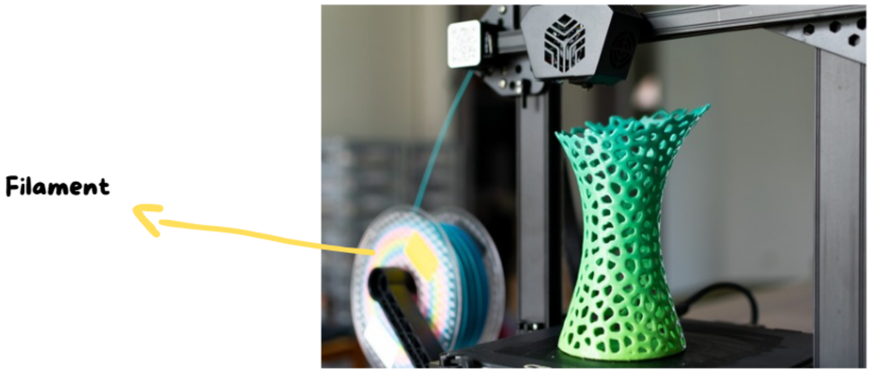

Figure 10: Filament of 3D printer [18].

Step 3- Introduction to digital design (CAD)

This step should begin with intuitive, easy-to-use tools such as Tinkercad, which allow students to design simple objects without needing much prior knowledge. Once they have mastered this program, they can move on to other more professional and precise programs, but this is a good one to start with and understand the design process.

Step 4- First impressions

It is recommended to start practical work with simple, ready-made projects. These exercises allow students to focus on how the machine works without overwhelming them with too many concepts. Ready-to-download models can be found online and sent to print.

Step 5- Progressive integration into woodworking projects

Once students understand the basic theoretical concepts and operating rules, projects related to the curriculum can be introduced directly, such as furniture models, useful templates for the woodworking shop, joints for wood pieces, or decorative pieces.

3D printing is very well suited to project-based learning and allows students to go through all the phases of it, but it is important to teach theory of use and safety rules before trying it in practice.

Step 6- Review and evaluation of parts

After each print, it is important to analyze the results with the students, review tolerances, check the style of the part, design errors, etc. This is useful for students to develop critical thinking and improve their techniques.

Step 7- Management and maintenance

It may also be advisable to give students responsibilities in the classroom.

3D printers require basic maintenance, and it is a good idea to assign roles to help the teacher manage the machines and materials. Students can be responsible for checking the remaining filament, cleaning, organizing files for printing, and even supervising the equipment.

This methodology helps to give students autonomy and responsibilities [14], [15], [16], [19].

4.3 Classroom Integration Checklist

Once teachers are ready to integrate 3D printing into their lessons, this checklist provides an at-a-glance guide to preparing, running, and closing a classroom activity. It ensures that all necessary materials, tools, digital resources and pedagogical steps are ready, helping instructors manage the session smoothly and safely.

Preparation for the session

- ☐ You have selected a simple, ready-to-print model for beginners.
- ☐ All required files (STL and G-code) are saved and backed up.
- ☐ The printer was pre-tested the day before to avoid surprises.
- ☐ Time estimate for each print is realistic for a class period.
- ☐ Students have access to CAD tools appropriate to their level (Tinkercad/Fusion/etc.).

Materials and tools

- ☐ Filament available (PLA recommended for classroom use).
- ☐ Scraper, tweezers, glue stick/tape (if necessary for bed adhesion).
- ☐ Spare nozzles or essential maintenance tools.
- ☐ A USB/SD card or Wi-Fi connection is ready for file transfer.

During the activity

- Students know their roles (file preparation, slicing, monitoring, documenting...).
- Students can identify the main printing parameters:
  - layer height
  - infill
  - supports
  - temperature
- A clear workflow has been explained: **Design → Slice → Print → Evaluate**.
- You have planned time for post-processing (removing supports, basic sanding).

After the activity

- Students document the results (photos, sketches, printing notes).
- A reflection activity is prepared (What worked? What failed? Why?).
- Printer is cleaned and ready for the next group.

4.4 Tips for teachers

Below are some recommendations regarding 3D printers for educational applications.

Recommendation	Description
Maintenance support	Before purchasing a printer, it is important to check whether the company that sold you the machine provides technical support for customers and whether they have easy access to replacement parts. This is important because it is not uncommon for printers to be damaged during use in the classroom, and more technical assistance may be required.
Safety	It is also important to be informed and know how to educate others about safety when using the 3D machine, since many people will use it and it must be used responsibly.
Size of the construction area	Depending on the size, we can design different objects. However, you don't need a large construction area to learn how to print in 3D. You can start with something simpler, as large prints take longer and cost more to

	complete, and may not be the best option at the beginning of this training.
Technology to use	As mentioned above, there are different types of 3D technology, so it is important to study all the possibilities to see which one best suit your students, classroom, and type of training. The most economical option to start with is FDM technology [20].

5. Safety and sustainability in 3D printing

3D printing technology is becoming increasingly common, but it is important to bear in mind that it carries certain risks, which, although not very serious, are nonetheless important to consider.

Use of personal protective equipment (PPE):

To protect against associated risks, it is essential to use appropriate personal protective equipment (PPE) to protect users from smoke inhalation or contact with hazardous materials.

- Respirators: These are necessary to prevent inhalation of harmful fumes or ultrafine particles emitted during printing. They are sometimes not necessary when using FDM 3D printing machines, as the parts being printed are not very large, but it is a factor to consider.
- Neoprene gloves: These gloves provide protection against chemicals and hot surfaces, as removing the part or making any movement can pose a risk.
- Splash-proof eye protection: to protect against splashes of liquid materials or process residues, it is recommended to wear safety glasses or visors.
- Fire-resistant coveralls: these suits can protect against skin exposure to hazardous chemicals or possible fires.

Ventilation:

On the other hand, adequate ventilation is also an important measure in 3D printing to maintain a healthy environment.

Effective ventilation systems reduce the concentration of airborne contaminants such as VOCs (Volatile Organic Compounds) or ultrafine particles. To do this, it is important to:

- Mechanical ventilation systems: install air extractors that capture and expel harmful emissions directly from the source, or install air purifiers with HEPA filters, as these can trap small particles.
- Regular air quality assessments: it is also advisable to monitor the air quality within the printing area to ensure that the ventilation systems are working properly.

- **Maintain negative pressure**: the printing area should maintain slight negative pressure relative to the adjacent rooms to prevent the spread of contaminated air.
- **Use of chemical absorbents**: integrating activated carbon filters is recommended to absorb VOCs and further improve air quality [21].

The 3D printer can reach very **high temperatures**, so it is important to follow these recommendations:

- Do not touch the nozzle or the heated bed while a piece is being printed.
- Keep the printer away from cables, fabrics, or any other flammable material.
- Constantly check the electrical connections.
- Always monitor the first layers of printing to ensure that everything is working correctly.

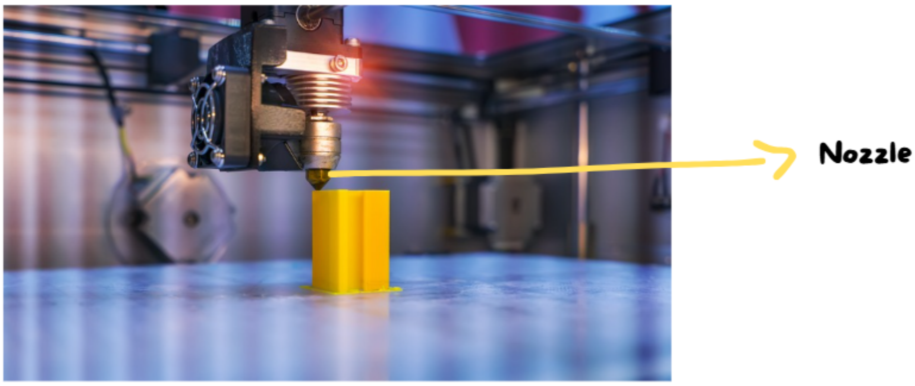

Figure 11: Nozzle of a 3D printer machine [22].

What about the waste generated by 3D printing?

With the waste that this can generate, which is not usually much since this technology is often a sustainable alternative, the following actions can be taken:

Reuse and repurpose: Before discarding printing waste, we can consider reusing it to test or refine future designs or convert leftover filaments into other useful designs.

Recycle: We can also recycle different types of filaments. PLA, on the one hand, is biodegradable and can be recycled perfectly. Filaments such as ABS or PETG can be melted down and used in new prints, if possible and if the center has the capacity to do so. Another somewhat less viable option is DIY filament extrusion, which is the process of grinding and melting failed prints to obtain new filament [23].

6. Additional resources

Title: FDM 3D Printing Tutorial

Author: UCSD Makerspace

Description: In this video, we can see a short theoretical and practical tutorial on how to use an FDM 3D printer.

Link: https://goo.su/f7KA

Title: Guide to 3D Printing

Author: Formlabs

Description: In this link you can learn how 3D printers work, explore the different types of 3D printers, materials, and explore applications of 3D printing.

Link: https://formlabs.com/3d-printers/?srsltid=AfmBOop31U6vY3A4DfpT4kC4hN7fggD0_pvgeniElRz70JmdG_DN0Sp6

Title: Loading & Removing 3d Printer Filament- A Beginner´s Guide

Author: Ricky Impey

Description: This video shows you how to load and remove filament from a 3D printer. It shows you what you need to do before loading it to start using it, and how to remove it when you want to change the material.

Link: https://goo.su/jxRwKlB

Title: 3D PRINTING 101: The Ultimate Beginner´s Guide

Author: The 3D Printing Zone

Description: Video tutorial on how to use the 3D printer.

Link: https://goo.su/UFRFV

Title: 3D Printing Guide for Teachers

Author: PrintLab

Description: More comprehensive guide on the use of 3D printing technology for teachers.

Link: https://www.stem.org.uk/system/files/elibrary-resources/2018/09/PrintLab%20-%203D%20Printing%20Guide%20for%20Teachers.pdf

7. Conclusion

3D printing is a very useful tool for modernizing woodworking VET. Its integration into the classroom allows students to design, create, test, and improve techniques and ideas creatively, connecting theoretical learning with real-world practice in the workshop.

This technology facilitates prototyping and customization of parts and also develops essential skills in students, such as critical thinking, problem solving, and teamwork. With good progressive planning and well-structured activities, 3D printing can be a motivating resource that can be aligned with the demands of this sector.

Incorporating them into VET training cycles is a commitment to creative and innovative teaching and helps prepare students for what is or will be required in the sector.

Let's commit to modernizing the sector and adapting to change!

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