COMPUTER NUMERICAL CONTROL TECHNOLOGY (CNC)

SHIFTVET

Digital Transformation for
Wood and Furniture VET

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Key terms

CAD (Computer-Aided Design)
Software used to design the shape, dimensions and features of a part before manufacturing.

CAM (Computer-Aided Manufacturing)
Software that converts a CAD design into machine instructions for CNC machining.

CAD–CAM–CNC Workflow
Digital workflow that goes from design (CAD), to toolpath generation (CAM), to physical machining (CNC).

G-code
Programming language used to control CNC machines, defining movements, speeds, cutting depth and tool actions.

Toolpath
The digital route that the cutting tool follows during machining, generated by CAM software.

EDM (Electrical Discharge Machining)
CNC process that removes material using electrical sparks; mainly used for metals, not common in woodworking.

PPE (Personal Protective Equipment)
Safety equipment such as safety glasses or hearing protection used during CNC operation.

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 CNC 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 centres 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 CNC machining into their teaching practice. As digital technologies increasingly shape the carpentry and manufacturing sectors, Computer Numerical Control (CNC) has become a key technology for precision machining, digital fabrication and efficient production workflows. Understanding its potential is essential to preparing students to operate in modern, technology-driven professional environments.

This guide has been specifically developed to help educators gain the knowledge, confidence and practical skills necessary to effectively use CNC in woodworking instruction. It offers a clear and accessible introduction to the fundamentals of subtractive digital manufacturing: what CNC is, how it works and why it is a critical complement to traditional woodworking techniques.

More specifically, this guide aims to:

- Build a solid foundation on the principles of CNC machining, including key concepts, machine components, axis configurations, cutting tools and essential CAD–CAM–CNC workflows.
- Clarify its relevance to woodworking, showing how CNC technology supports activities such as precision cutting, panel processing, joinery production, repetitive manufacturing, design validation and the machining of complex geometries, among other applications commonly used in the wood and furniture sector.
- Provide practical, classroom-ready strategies for incorporating CNC machines into VET programs, including lesson ideas, hands-on exercises, safety considerations and best practices for machine setup and operation.
- Support trainers with varying levels of experience by offering clear explanations and applied examples that make CNC technology accessible, including for educators with limited prior exposure to digital manufacturing systems.
- Strengthen the links between digital fabrication and traditional craftsmanship, helping students understand how CNC machining enhances accuracy, efficiency and repeatability while complementing, rather than replacing, conventional woodworking skills.

Ultimately, the purpose of this guide is to make CNC technology an accessible, motivating and educationally valuable resource for both trainers and learners, supporting the transition from traditional carpentry practices to digitally enabled professional workflows in the wood and furniture sector.

1.3 Who is the guide aimed at?

This guide is designed for vocational training instructors and educators in carpentry who wish to introduce CNC machinery 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 CNC into their classrooms and workshops.
- Vocational training providers and training centres are interested in modernizing their curricula and offering students access to relevant digital technologies.
- Educators in related technical or manufacturing fields who wish to understand how CNC technology can complement traditional craftsmanship, improve production accuracy and enhance learning experiences in vocational training contexts.
- 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 CNC machinery 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 CNC 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 CNC technologies, common materials, software workflows, and essential terminology.
3. Explore pedagogical applications- The guide includes examples and explanations illustrating how CNC 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 CNC?

CNC stands for Computer Numerical Control, and it refers to a way of using a computer to operate a machine automatically instead of relying on someone to control it manually. In simple terms, a CNC machine is a tool that follows digital instructions to cut, shape or work on material with little direct human control.

In this system, a programmed set of instructions, often created from a digital design, tells the machine exactly what movements to make, how fast to move, how deep to cut and where to stop. This means that once the instructions are ready, the machine can work more consistently and accurately than a person operating tools by hand.

Even though the machine works automatically, a trainer or operator still needs to prepare the design, load the instructions and check that everything is set up correctly before starting the job. Their role is to make sure the machine cuts the material in the right way and that the process is safe.

In woodworking, CNC machines are typically used to cut shapes, drill holes, make grooves and produce parts that need to be the same every time, for example, repeated components of furniture or complex patterns that are difficult to do by hand.

Key ideas you should remember:

- CNC machines read computer instructions, not manuals or levers
- They are designed to help with precise and repeatable work
- They do not remove people from the process, but they support people by reducing the need for manual control for each cut [1].

Figure 1: CNC machine [2].

2.2 How does CNC works?

When we talk about how CNC works, we can think of it as a sequence of steps that take a piece from an idea on a computer to a real object made with a CNC machine. According to a step-by-step breakdown of the CNC workflow, these steps are:

First step- Design the product on the computer:

The first thing is to create a digital design of the piece you want to make. This is done using CAD software, where you draw the shape, size and features so that it can be understood by both people and machines.

Step two- Develop the CNC program:

Once the design is ready, it needs to be translated into instructions that the CNC machine can follow. These instructions are written in a language such as G-code and tell the machine where to cut, how fast, and with which tool.

Step three- Simulate and check the program:

Before running the machine, many CNC systems let you simulate the process on a computer. This means you can see how the cutting tool will move and check for mistakes before any wood is cut, which helps prevent crashes or errors.

Step four- Set up the machine:

Now you prepare the physical machine:

- Install the correct cutting tool
- Secure the piece of wood
- Set the starting position

- Adjust machine settings like speed and feed. This setup makes sure the machine can follow the instructions correctly.

Step five- Machining (the CNC cuts the part):

This is the core stage where the machine follows the program and cuts the material. The CNC tool moves precisely according to the instructions to shape the piece exactly how it was designed.

Step six- Monitor and check quality during cutting:

While the machine works, it's important for the trainer or operator to watch the process and measure parts to make sure everything stays on track. If something doesn't look right, adjustments can be made before too much material is removed.

Step seven- Finishing and post-processing:

After the machine finishes cutting, the piece may need final touches such as sanding, polishing or assembly to reach the final quality desired. This can happen after the CNC step and is part of completing the product [3].

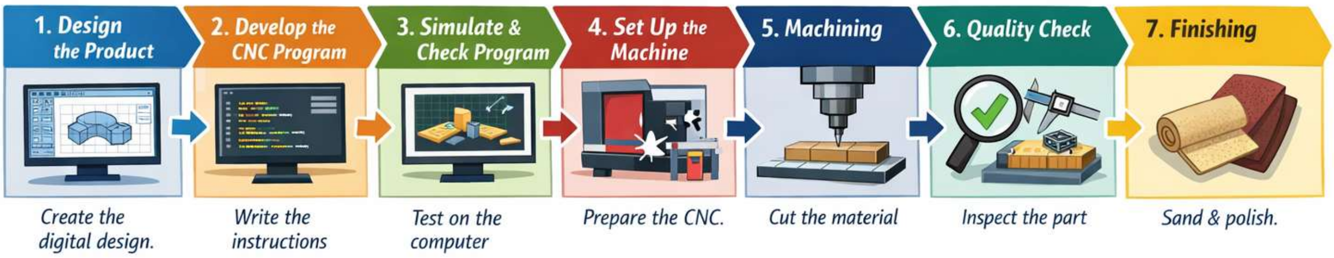

Figure 2: CNC steps. Open AI 2026.

2.3 Types of CNC cutting processes

There are many kinds of CNC technology, each designed to do specific jobs by moving tools accurately according to a computer program. These technologies vary by how they cut or shape material and what materials they work best with.

Below is an overview of the most common types of CNC technologies, written in plain language for VET instructors and carpentry educators:

CNC Router

A CNC router is very common in woodworking. It works like a computer-controlled cutting tool that moves in several directions to cut shapes, profiles and features in wood and wood-based panels.

This is good for furniture parts, decorative panels and repeatable production. Routers are essentially milling machines adapted for wood and lighter materials.

CNC Milling Machine

CNC milling machines remove material using a rotating cutting tool. They can cut flat surfaces, curves and complex shapes with good precision. Milling is widely used in many industries, including woodworking when precision is needed.

CNC Lathe

A CNC lathe works differently because the workpiece rotates while the tool stays in place and cuts. This makes it ideal for creating cylindrical or round parts like dowels, legs, knobs or turned furniture elements.

CNC Laser Cutter

Plasma cutters use ionized gas at high temperature to cut metal. They are fast and effective on thicker conductors like steel but are not typically used for wood.

CNC Waterjet Cutter

Waterjet cutters use a high-pressure jet of water, often mixed with abrasive particles, to cut materials.
They don’t generate heat, so they’re good for heat-sensitive materials like plastics or composites.
They can also cut tough materials that might melt or deform under heat.

CNC Electroerosion (EDM)

EDM (Electrical Discharge Machining) uses electrical sparks to erode material from a part.
It’s very good for hard materials and complex shapes, especially when other methods struggle. This type is usually used for tools, dies and metalwork, not common in basic woodworking [4].

2.4 General applications

CNC technology is used in woodworking to cut, shape and prepare wooden parts in a precise and repeatable way. Instead of working each piece by hand, CNC allows the same design to be made accurately, multiple times, using a digital file as a reference.

Below are the main general applications of CNC in woodworking.

It is used for furniture production. CNC machines are widely used to produce parts for furniture, such as tables, chairs, cabinets and shelves. The machine cuts panels and components so they fit together correctly, helping to ensure consistent quality across multiple pieces. It is also useful for cabinetry and fitted furniture such as kitchen cabinets, wardrobes and built-in furniture, where precision is important. It allows accurate cutting of panels, slots and holes so parts align properly during assembly.

Another application of this technology is for joinery and connections because CNC can create joints, grooves and connection details that would be difficult or time-consuming to make by hand. This helps students understand how digital tools support traditional woodworking techniques. One of the most visible applications of CNC is decorative work, such as carving patterns, letters, logos or textures into wood. This is commonly used for signage, panels and artistic elements.

CNC machines are also used to make prototypes or test pieces before final production. This helps check dimensions, fit and appearance before committing to a full batch.

Finally, it is also useful for small objects, crafts and educational projects such as wooden toys, learning projects or craft objects. These applications are particularly relevant in training environments, where learning by making is important [5], [6].

Figure 3: CNC piece [7].

2.5 Required equipment

Working with CNC in a woodworking training context means you need some basic tools and equipment that allow you to go from a digital design to a finished wooden piece. CNC machining is a controlled process that removes material from a block using machines and cutting tools driven by computer instructions.
Below are the main pieces of equipment that are typically involved:

1. CNC machine: This is the core machine that does the cutting. CNC machines are controlled by computer programs that move the cutting tool and remove material to shape the part you want. There are different types of CNC machines, but the key idea is that the machine frame, motors, electronic controller and spindle with cutting tools work together under computer control to make the design.
2. Computer and software (CAD+CAM): To operate a CNC machine you need a computer with suitable software: CAD (Computer-Aided Design) software to make or open the design of the piece. CAM (Computer-Aided Manufacturing) software to generate the instructions the machine will follow. This combination allows the design to be translated into a program of movements and cutting actions that the CNC machine understands.
3. Cutting tools: CNC machines do not cut wood with their bare metal parts; they use cutting tools such as end mills or router bits. These tools are fixed into the machine's spindle and are responsible for removing material from the wood. The choice of tool affects the type of cut, the finish quality and how long the tool lasts.

Figure 4: CNC router bits [8].

4. Work holding fixtures: For the machine to cut without mistakes, the piece of wood must be held securely in place. This is done using: clamps, fastening plates and fixtures designed for specific shapes.
   Secure work holding prevents movement during cutting so that the machine can follow the program accurately.
5. Material blocks or blanks: You need the raw wooden stock that is the piece of wood or panel from which the final part will be shaped. In machine shops this is sometimes called a “blank” or “workpiece.”
6. Measurement and finishing tools: After the CNC machine cuts the piece, you often do some manual finishing such as sanding, checking dimensions with rulers or callipers, or assembling parts. These traditional tools complete the CNC workflow in a woodworking context [9].

2.6 Technical Setup Checklist

Before starting any classroom activity with CNC machining, it is essential to make sure that the machine, tools and digital files are properly prepared and safe to use. The following checklist summarizes the key elements that teachers should verify before running a CNC job. Use it as a quick-reference tool to ensure accuracy, safety and smooth operation during the activity.

Equipment readiness

- ☐ The CNC machine is installed in a stable, clean and well-ventilated workshop area.
- ☐ The machine has been powered on and checked with no visible error messages.
- ☐ The cutting tool (router bit) is correctly installed and securely tightened.
- ☐ The selected tool is appropriate for the material and operation (cutting, engraving, slotting).
- ☐ The workpiece (wood or panel) is firmly fixed to the machine table (clamps or vacuum).
- ☐ The machine zero point (starting position) has been set correctly.
- ☐ There is enough material thickness to complete the operation safely.
- ☐ The CNC software is up to date and compatible with the machine controller.
- ☐ The CNC program has been reviewed (tool paths, cutting depth, speeds and feeds).

Safety checks

- Students have been informed about moving parts and rotating tools.
- Long hair, loose clothing and jewellery are secured or removed.
- Safety glasses and hearing protection are available and used when required.
- Emergency stop buttons are clearly identified and accessible.
- Clear instructions are given on where students can stand and what they must not touch while the machine is running.

Digital resources

- You have access to CAD software for last-minute design changes.
- The CNC program was generated using CAM software suitable for the machine.
- Design files have been checked for correct dimensions and scale.
- Files from external sources are appropriate for educational use and legally usable in the classroom.

Common beginner mistakes and risks in CNC machining

When working with CNC machines for the first time, beginners often make mistakes that can affect the quality of the work or create safety risks if not properly addressed.

One of the most common mistakes is incorrect workpiece fixation. If the material is not securely clamped or fixed, it may move during machining, leading to inaccurate cuts or tool damage. Another frequent issue is incorrect zero-point setting, which can result in cuts being misplaced or too deep.

Beginners may also select inappropriate cutting tools or parameters, such as incorrect feed rates or spindle speeds, which can cause poor surface finish, tool wear, or burning of the wood. Skipping simulation or program review is another risk, as undetected errors in the toolpath can lead to collisions or material waste.

Addressing these mistakes early helps students develop safe habits and understand the importance of preparation and verification before machining.

3. Potential of technology in woodworking VET

3.1 Educational benefits

Introducing CNC technology into vocational education provides a range of educational benefits that support both technical learning and student engagement. When used in the classroom or workshop, CNC helps connect digital skills, hands-on making and real-world applications.

Hands-on learning with real-world relevance:

CNC machines allow students to work with the same type of technology used in professional workshops. Learners do not only study concepts but apply them directly by designing parts and seeing them manufactured. This practical approach helps students understand how their skills connect to real jobs.

Development of problem-solving and critical thinking:

Working with CNC encourages students to plan, test and adjust their ideas. If a part does not come out as expected, students must analyse what went wrong and improve the design or setup. This process strengthens problem-solving skills and logical thinking.

Strong connection between digital design and physical making:

CNC helps students clearly see the link between computer-based design and physical production. Designing a part on screen and then producing it on a machine makes abstract ideas more concrete and easier to understand.

Increased student engagement and motivation:

CNC machines tend to capture students' interest, especially because they produce visible, professional-looking results. Seeing a machine transform a digital file into a real object helps keep students motivated and involved in the learning process.

Support for creativity and project-based learning:

CNC technology allows students to create custom parts and original designs, which supports creative thinking. It is well suited to project-based learning, where students design, produce and improve their own work overtime.

Preparation for future careers and further training:

Learning to use CNC machines helps students become familiar with modern manufacturing environments. This experience can support future employment, apprenticeships or continued technical education by building confidence with industry-relevant tools [10], [11].

3.2 Technical advantages of CNC in Vocational Training for woodworking and carpentry

From a technical perspective, CNC technology provides clear advantages when used in vocational training for woodworking and carpentry. One of the most important benefits is precision, as CNC machines follow digital tool paths that allow accurate cuts, clean edges and correctly sized components. This makes it easier to achieve reliable technical results compared to fully manual processes.

Another key advantage is repeatability. Once a CNC program has been created, the same part can be produced multiple times with consistent quality. This is especially useful in training environments, where students can work on similar tasks under the same technical conditions and results can be compared more easily.

CNC machines also make it possible to produce complex shapes and detailed features, such as curves, slots or decorative elements, that would be difficult or very time-consuming to create by hand. This expands the range of woodworking projects that can be carried out in VET workshops.

In addition, CNC machining supports more efficient use of materials, as cutting paths can be planned to reduce waste and avoid errors. Once set up, CNC machines can also perform repeated operations efficiently, helping workshops make better use of limited training time.

Overall, these technical advantages make CNC a practical and reliable technology for VET in woodworking and carpentry, aligning workshop practices with those used in modern professional environments [5], [6].

Just for clarification, CNC machining and manual woodworking should not be seen as opposing methods, but as complementary approaches that serve different purposes within woodworking and carpentry.

Manual woodworking develops fundamental skills such as material awareness, hand-eye coordination and craftsmanship. It allows students to understand wood behavior, grain direction and finishing techniques through direct physical interaction.

CNC machining, on the other hand, offers precision, repeatability and efficiency, making it ideal for producing accurate components, complex geometries and repeated parts. CNC is especially useful for tasks that require consistent results or detailed patterns that are difficult to achieve by hand.

In vocational training, combining both approaches allows students to benefit from the strengths of each method. CNC supports accuracy and efficiency, while manual woodworking reinforces traditional skills and craftsmanship, resulting in a balanced and comprehensive learning experience.

3.3 Pedagogical checklist

Introducing CNC technology in VET woodworking is not only a technical task, but also a pedagogical opportunity.

Before designing classroom activities, teachers should ensure that learning objectives, student readiness and curriculum alignment are clearly defined. This checklist helps ensure that CNC is used in a meaningful, motivating and educationally effective way.

Learning goals

- ☐ The activity aligns with woodworking or carpentry curriculum.
- ☐ Students understand the basic CNC workflow (design, programming, setup and machining).
- ☐ The task reinforces problem-solving and decision-making, such as choosing tools, settings or strategies.
- ☐ The activity includes hands-on interaction with both digital tools and physical materials.

Pedagogical preparation

- ☐ You have prepared or machined an example piece to show the class.
- ☐ You have identified common CNC issues students may encounter (incorrect zero-point, tool selection, feed rate problems, poor fixing of the material).
- ☐ You have prepared guiding questions such as: *Why is the cut inaccurate? What needs to be adjusted?*
- ☐ You have planned moments for peer collaboration and group discussion during design, setup or evaluation.

Material adaptation for woodworking

- ☐ The CNC activity is clearly connected to real woodworking processes (cutting panels, joinery elements, slots, fixtures or decorative parts).

- Students can compare CNC-machined parts with manually produced components.
- You have examples that show how CNC supports and enhances craftsmanship, rather than replacing traditional woodworking skills.

3.4 Example of activities for woodworking VET

To help teachers visualise how CNC technology can be integrated into woodworking training, the following examples present ready-to-use activities that can be adapted to different levels and workshop contexts.

These activities show how CNC machining can support learning, precision work, joinery understanding and experimentation in carpentry.

Short project- Beginner level (1–2 sessions): CNC machining a simple workshop component

- Objective: Introduce students to the basic CNC workflow using a simple and functional object that can be used directly in the woodworking workshop.
- Description: Students download or create a simple design such as a spacer block, cutting stop or drilling template. They prepare the CNC program, set up the machine, machine the part and then test it in a real woodworking task. The focus is on understanding the process rather than complexity.
- Learning outcomes: Understand the basic CAD–CAM–CNC workflow; Observe the importance of dimensions, accuracy and tolerances; Connect CNC-machined parts with practical workshop use.
- Variation: Students modify the design to fit a specific machine, tool or measurement used in their workshop.

Medium project- Intermediate level (3–4 sessions): CNC-assisted joinery exploration

- Objective: Explore traditional joinery concepts using digital design and CNC machining to better understand fit, geometry and precision.
- Description: Students design a joint using CAD software and machine a test version using CNC. They check how well the parts fit, identify problems, adjust the design if needed and then produce the joint in real wood. This approach helps students understand joint behaviour before committing to final pieces.

- Learning outcomes: Develop basic CAD and CNC preparation skills; Analyse fit, alignment and mechanical behaviour of joints; Reduce material waste by testing designs digitally and incrementally.
- Variation: Students compare different joint designs and present which solution works best and why.

Longer project- Advanced level (1–2 weeks): Designing and manufacturing a CNC-based woodworking object

- Objective: Combine traditional woodworking skills with digital CNC machining in a complete project.
- Description: Students design an object that includes CNC-machined wooden parts, such as panels with slots, curved elements or precise cut-outs. They prepare the design; machine the parts using CNC and then assemble and finish the object using traditional carpentry techniques.
- Learning outcomes: Understand the complementary role of CNC machining in woodworking; Plan a project from design to machining to assembly; Apply both digital and manual skills in a single coherent task.
- Variation: Students document the full process (design- CNC machining-assembly- finishing) and reflect on the advantages and limitations of using CNC.

4. Integration in the classroom

4.1 Methodological recommendations

According to 3ERP, the use of CNC technology in education represents a significant opportunity to strengthen vocational and technical training by bringing learning closer to real industrial practice. CNC machines are widely used in modern manufacturing environments, and their introduction in educational settings allows students to work with tools and processes that closely resemble those found in professional workshops. This helps reduce the gap between what students learn in the classroom and what they are expected to do in the workplace.

One of the main contributions of CNC in education, is its ability to support hands-on, experiential learning. Instead of focusing only on theoretical explanations, students actively participate in designing parts, preparing machine programs and observing how digital instructions are translated into physical objects. This direct involvement helps learners better understand manufacturing processes and reinforces technical concepts through practice.

3ERP also points out that CNC-based activities encourage the development of problem-solving skills. During CNC projects, students often face challenges related to design accuracy, machine setup or unexpected results. To overcome these issues, they must analyse what went wrong, adjust parameters or modify designs. This iterative process promotes critical thinking and helps students learn how to approach technical problems in a structured and methodical way.

In addition, working with CNC technology exposes students to digital workflows, including the use of design files and machine-controlled processes. This experience supports the development of digital competence alongside traditional technical skills. Students learn not only how to operate machines, but also how to plan, test and refine their work, which reflects common practices in contemporary manufacturing.

Finally, it emphasises that early exposure to CNC technology can improve students' career readiness. Because CNC machining is a core technology in many industries, familiarity with CNC systems can make students better prepared for entry-level positions, apprenticeships or further technical education. In this sense, CNC serves not only as a learning tool, but also as a bridge between vocational education and future employment opportunities [10].

4.2 Step-by-step implementation plan

Step 1- Planning and curriculum alignment

Before introducing CNC in the workshop, define clear learning objectives and ensure they align with the woodworking or carpentry curriculum. Decide what students should learn at each stage like basic workflow, accuracy, joinery, or project development, and select activities that match their experience level.

Step 2- Teacher preparation and familiarization

Teachers should become familiar with the CNC machine, software and basic workflow before working with students. This includes running test jobs, identifying common mistakes and preparing example designs or finished parts to use during demonstrations.

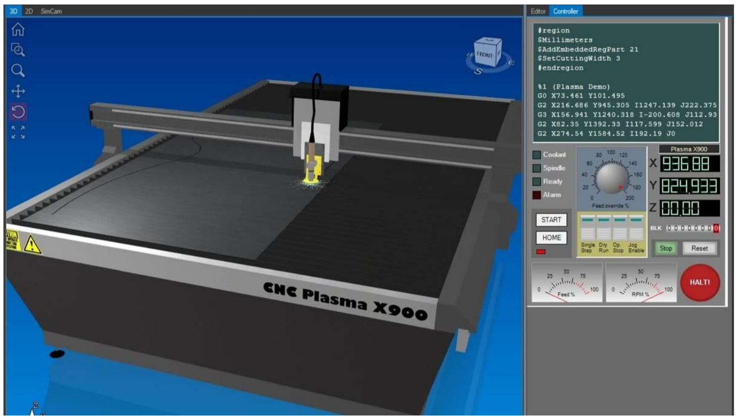

Figure 5: Software for CNC [12].

Step 3- Introducing CNC concepts to students

Explain what CNC is and how it fits into woodworking practice using simple language and real examples. Short demonstrations help students understand the process before they begin working with the machine themselves.

Step 4- Guided hands-on practice

Start with simple, supervised activities. Students work on basic designs or small CNC tasks while the teacher provides close guidance, focusing on safety, correct setup and understanding each step of the process.

Step 5- Progressive student autonomy

As confidence grows, students take on more responsibility in design decisions, machine setup and problem-solving. Tasks can gradually increase in complexity, moving towards joinery elements or small projects.

Figure 6: Student using CNC machine [13].

Step 6- Integration with traditional woodworking tasks

Combine CNC machining with manual operations such as assembly, sanding and finishing. This helps students understand how CNC supports, rather than replaces, traditional woodworking skills.

Step 7- Evaluation and reflection

After each activity, review the results with students. Discuss what worked well, what problems appeared and how the process could be improved. Reflection helps consolidate learning and develop technical reasoning.

4.3 Classroom Integration Checklist

Once teachers are ready to integrate CNC machining into their lessons, this checklist provides a 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 CNC task suitable for beginners (e.g. spacer, stop block, simple panel cut).
- ☐ All required digital files (CAD and CNC program) are saved and backed up.
- ☐ The CNC machine was tested the day before to avoid unexpected issues.

- The estimated machining time fits within the available class period.
- Students have access to CAD software appropriate to their level.
- The CNC workflow has been planned: Design- Program- Setup- Machine- Evaluate.

Materials and tools

- Suitable wood or panel material is available and prepared.
- Appropriate cutting tools (router bits) are installed or ready.
- Clamps or vacuum system are available to fix the workpiece securely.
- Measuring tools (ruler, caliper) are ready for checking dimensions.
- Dust extraction system is connected and operational.
- Required PPE is available (safety glasses, hearing protection).

During the activity

- Students know their roles (design, setup, monitoring, quality check, documentation).
- Students can identify the main CNC parameters, such as:
  - cutting depth
  - tool type
  - feed rate
  - spindle speed
- A clear workflow has been explained: Design- CNC program- Setup- Machining- Evaluation.
- The teacher actively supervises machine operation and student positioning.
- Time is planned for basic finishing (edge sanding, cleaning).

After the activity

- Students document the results (photos, sketches, notes on settings and outcomes).
- A short reflection activity is carried out (What worked? What didn’t? What would you change?).
- The CNC machine is cleaned, tools removed if needed, and workspace left safe for the next group.

4.4 Tips for teachers

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

Recommendation	Description
Start with simple CNC tasks	Begin with basic operations such as straight cuts or simple shapes before moving to complex projects. This helps students understand the CNC workflow.
Demonstrate before letting students operate	Short demonstrations allow students to visualise the process, machine movements and safety zones before they take an active role in CNC activities.
Integrate CNC with traditional woodworking	Combine CNC machining with manual tasks like assembly, sanding and finishing so students understand CNC as a complementary tool, not a replacement for craftsmanship.
Emphasise safety at every stage	Regularly remind students about moving parts, rotating tools and safe positioning. Clear rules and supervision are essential for safe CNC use.
Encourage problem-solving and reflection	Treat mistakes as learning opportunities. Discuss why errors occurred and how design, setup or parameters can be improved.
Plan roles and teamwork	Assign clear roles (design, setup, monitoring, quality control) to involve all students and reflect real workshop practices.
Allocate time for evaluation	Always include time to review results, compare them with the design and reflect on the CNC process and outcomes [10], [11].

5. Safety and sustainability in CNC

The use of CNC technology in woodworking and carpentry training offers many advantages, but it also requires careful attention to safety and sustainability. In a VET context, CNC machines must be used in a way that protects students and teachers while also encouraging responsible use of materials and resources.

Safety considerations when using CNC machines:

CNC machines involve moving parts, rotating tools and electrical components, which means that safety must always be a priority. According to Proto&Go, one of the most important safety principles is ensuring that only trained users operate the machine and that clear operating procedures are followed. Before starting any CNC activity, users should be familiar with the machine controls, emergency stop functions and basic operating rules.

Proper personal protective equipment (PPE) is also essential. Safety glasses are recommended to protect against chips and debris, and hearing protection may be necessary depending on the machine and material being used. Loose clothing, jewellery and long hair should be secured to prevent contact with moving parts.

Another key aspect of safety is machine setup and workspace organisation. It is highlighted the importance of securely fixing the workpiece to prevent movement during machining. Tools must be correctly installed and tightened, and the cutting area should be kept clear of unnecessary objects. A clean and organised workspace reduces the risk of accidents and improves visibility during operation.

Regular inspection and maintenance also play an important role in safety. Checking tools for wear, ensuring guards and safety systems are functional, and keeping the machine clean help prevent malfunctions and unexpected failures. In an educational environment, these checks should be part of routine preparation before each session.

Figure 7: Person using proper personal protective equipment [14].

Sustainability aspects of CNC use in woodworking:

In addition to safety, CNC technology can support more sustainable practices in woodworking when used responsibly. One important sustainability aspect is material efficiency. Because CNC machining is planned digitally, cutting paths can be optimised in advance, helping reduce material waste and avoid unnecessary errors. This is particularly relevant in training environments where resources are limited.

CNC machines can also contribute to better control of production processes, which helps minimise rework and rejected parts. Producing accurate components from the first attempt reduces wasted wood and energy consumption associated with repeating tasks.

Another sustainability consideration is dust and waste management. Both sources stress the importance of proper dust extraction systems, which not only improve safety but also reduce the environmental impact of airborne particles in the workshop. Collected wood waste can be managed more effectively and, where possible, reused or recycled.

From an educational perspective, CNC provides an opportunity to raise student awareness about responsible manufacturing. By discussing material choice, cutting strategies and waste reduction during CNC activities, teachers can help students understand how digital tools can support more sustainable woodworking practices [14], [15].

6. Additional resources

Title: Introduction to CNC Machines
Author: CNCKing **Description:** Short video introducing what is CNC and how does it work. **Link:** https://www.youtube.com/watch?v=-C_h7BOq4ps
Title:
Author: The ultimate Guide to CNC Machining **Description:** Additional information and resources for learning more about this technology and its potential uses. **Link:** https://www.fictiv.com/articles/the-ultimate-guide-to-cnc-machining
Title: CNC Machining Types and Applications
Author: YIJIN Hardware **Description:** Short video introducing the different types of CNC machines that exists and can be applied. **Link:** https://www.youtube.com/watch?v=u1jiod4c-eI

7. Conclusion

The integration of CNC technology in woodworking and carpentry VET programmes supports the modernisation of VET by connecting digital processes with traditional craftsmanship. CNC allows learners to work with tools and workflows that reflect current professional practice, while still developing essential manual skills.

This guide has shown how CNC can be introduced in a structured, safe and pedagogically meaningful way, providing teachers with practical recommendations, examples of activities and guidance on classroom implementation. When used as a complementary tool, CNC enhances precision, supports learning and encourages a better understanding of production processes.

Within the framework of the ShiftVET project, this guide contributes to strengthening VET provision by supporting the adoption of innovative technologies aligned with labour market needs. In doing so, it helps prepare learners for the challenges of contemporary woodworking and carpentry professions.

ShiftVET is where CNC meets modern craftsmanship.

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