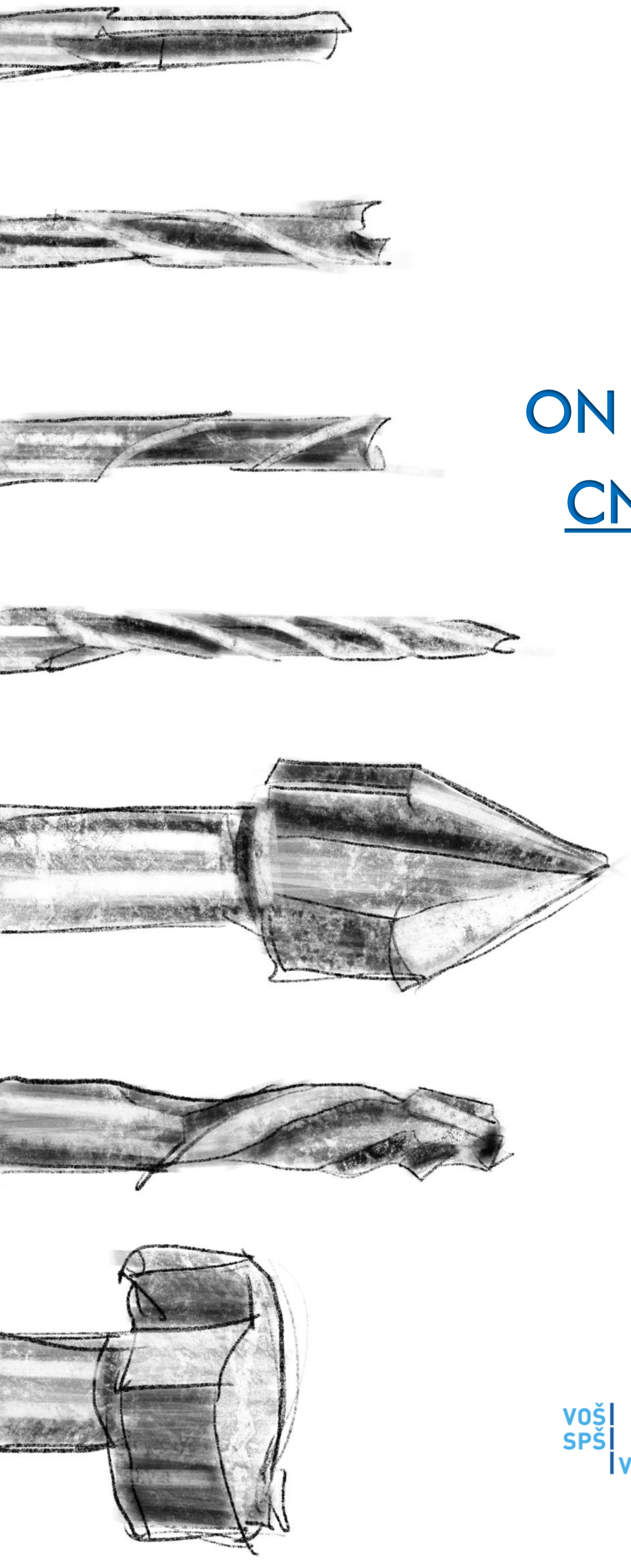
Co-funded by the
Erasmus+ Programme
of the European Union



METHODOLOGY OF SUCCESSFULL EDUCATION ON WOODWORKING CNC TECHNOLOGY

authors:

Jiří Procházka

Igor Hovnik

Richard Kminiak

and collective

VOŠ SPŠ VOLYNĚ

TECHNICAL UNIVERSITY IN ZVOLEN

Co-funded by the Erasmus+ Programme of the European Union

“Collective of authors participating on the development of this methodology comprises of people who gave important ideas by consultations, helped the main authors by feedback or designed the final look of pages. Many thanks go specially to following people”

Barbora Lhotová – design of pages

Marjan Prelog – technical consultation

Jiři Homolka – feedback

Andreja Paserl – International cooperation consultation

Petr Červený – technical consultation and feedback

Alena Havelková – language correction

Co-funded by the
Erasmus+ Programme
of the European Union

Table of contents

Co-funded by the Erasmus+ Programme of the European Union

Foreword

This methodology is focused on the teaching of CNC technologies in the field of woodworking and reflects the current problem of vocational education, which relates to the rapid development of technologies, to which educational institutions of secondary and higher vocational education generally respond with difficulty and slowly. The result of insufficient and/or unrapid reflection of the development is currently the lack of properly profiled candidates on the labour market.

First, it is necessary to compile a profile of the graduate in the field of professional knowledge. This profile will also serve as the objective of this methodology. CNC technologies are generally very complex, and therefore the profile of a graduate must include broad-spectrum knowledge and skills from many areas.

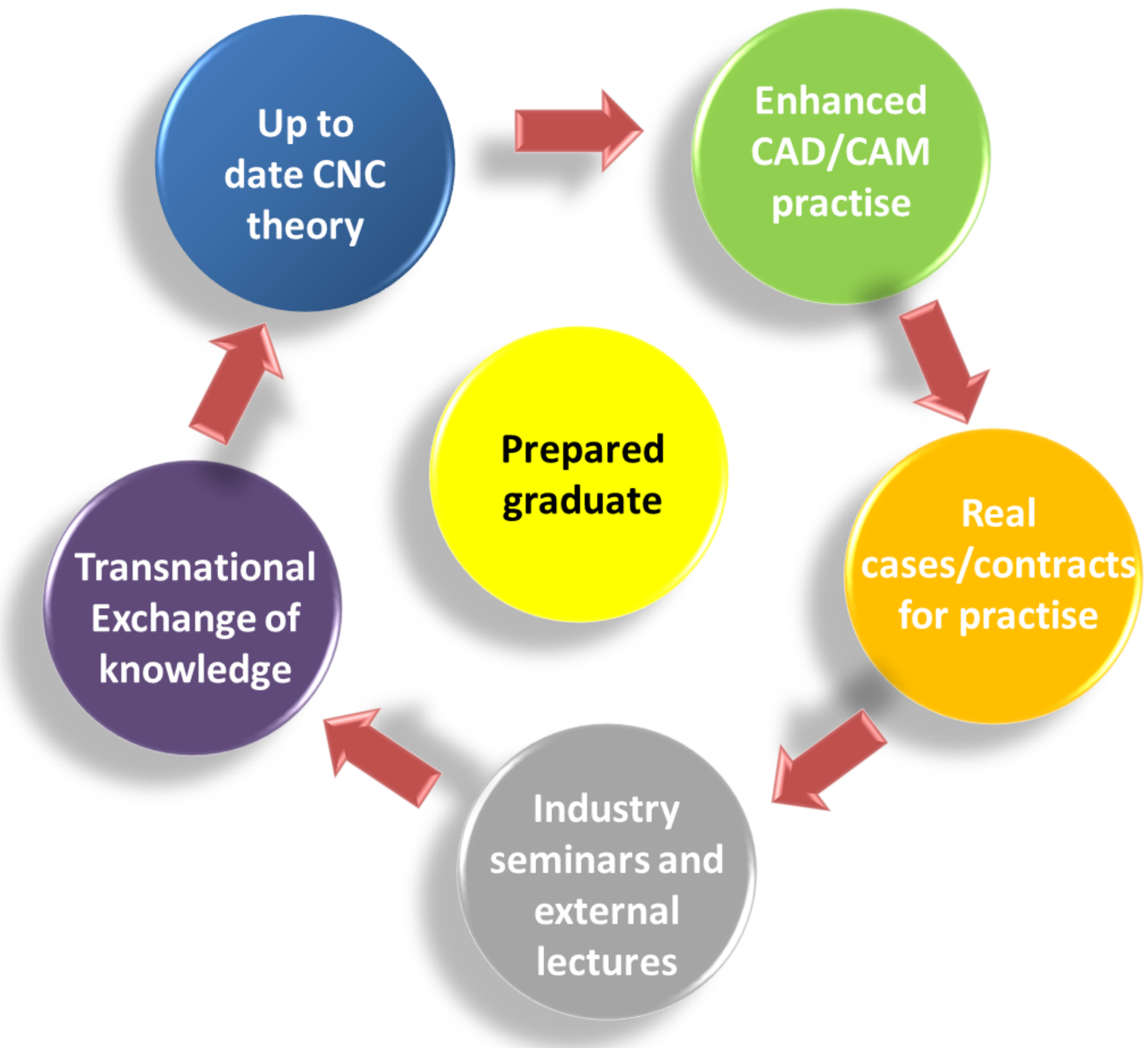
If we present a model example from practice, we can better understand the emphasis on the complexity of CNC technology teaching and subsequently identify important areas of knowledge. We have an order from the customer for a product that needs to be manufactured using CNC technology and will be produced in multiple material designs (solid wood spruce/oak/laminated chipboard).

In the first phase, a properly profiled student must be able to practically create a product design into a production drawing or 3D model - applied knowledge of CAD systems in 2D and 3D is therefore required*. The structure itself shown in the drawing already requires knowledge of the choice of suitable structural joints for CNC production in furniture construction. If we go further into the production preparation, i.e., to the phase of CAM systems that the graduate must master, the situation is even more complex. A part is displayed on the screen in 2D or 3D, which corresponds to the geometry and construction from the drawing. A properly profiled student now must master three basic phases – choosing a tool, choosing a technology, and setting up technologies, including their sequence. These stages combine knowledge of tools, machining technology, wood-based materials, and production equipment. The last step is the production itself, where it is necessary to correctly position and clamp the part, taking into account the possibilities of the machine and the machining technology, so it is necessary to master the production practically, because even at this stage, an error in the design can be found, i.e. at the very beginning of the entire process - for example, the workpiece cannot be clamped, or the tool cannot reach the machined location. A graduate's profile must therefore include practical training, during which the student will best gain a broader insight into the entire issue.*

From the model example, three basic pillars can be identified in the field of CNC woodworking technology education. The first pillar is "Theoretical Expertise", which is achieved by the classical model method (interpretation => understanding, memorization). The second pillar "Preparation for production" is an intermediate level where neither pure theory nor practice can be applied and includes subjects where the student trains practically, applies theoretical knowledge, but does not create material outputs. The third pillar is "Practical production", where the student learns the practical production of real products on a CNC machine.

Co-funded by the Erasmus+ Programme of the European Union

Above, the student profile was identified, which was divided into three pillars. These are the basis for the correct preparation of the graduate for real production. But the assumption is that this knowledge is passed on by the teacher, who also must gain such a knowledge somewhere. In this area, it is impossible for a teacher to draw on the times of his studies, and therefore it is necessary to follow contemporary developments in the commercial sphere and industry. It is therefore necessary to add another pillar "Cooperation with the commercial sphere". Finally, it is very important for the teaching staff to gain experience and teaching methods from schools with a similar focus in the country and especially abroad, which is why the last fifth pillar of the "Inter-institutional cooperation" methodology was created. Methodology concept is then based on five main pillars which can be described on the graphical model bellow.



Co-funded by the Erasmus+ Programme of the European Union

Pillar I: Theory education

A successful system for providing theoretical teaching in the field of CNC wood processing must reflect the nature of the field itself, which, as mentioned above, is complex. This is because, unlike the times before the advent of these technologies, individual actions could be better segmented because they were not so dependent on each other. For this reason, the methodology of education in this field cannot target only certain subjects, but must comprehensively include all professional, but often also general subjects that are taught as part of the educational program. Therefore, it is not possible to introduce one new course dedicated to the teaching of CNC technologies into the program, but it is essential that individual professional courses intertwine these technologies.

1. Human resources

The main prerequisite for properly functioning education is properly educated teaching staff. As can be seen from the issues described above, CNC technologies affect most professional subjects and it is extremely important to adjust the information conveyed in these subjects as well, so that the student has a wide-angle view. Therefore, the teacher of professional subjects must enrich his interpretation sufficiently so that it meets the prerequisites within the framework of the **correct orientation, the timeliness of the information**, which will be based on practical experience. In an ideal state, the quality of teaching can be evaluated by the following criteria.

a) Specialization

Every vocational education pedagogue should have one or more specializations within their field, to which they devote themselves in the long term. Only in this way can he be an erudite expert who conveys relevant information to the student. However, it is highly desirable for him to follow the teaching of his fellow specialists in other fields so that the teaching is interwoven and connected. Regarding CNC technology, this is doubly true, as the level of complexity is high here. The pedagogue himself should communicate sufficiently with others not only within the field or subject committees, but individual committees should also communicate with each other. Every educator should also try to follow new technologies and innovations in the field. **It will be very helpful for each teacher to visit a company that deals with production close to the topic he is teaching at least once a year**. It is also very important to pass it on to other colleagues. For this purpose, it is ideal to organize an internal disciplinary seminar at least once in two years, where each teacher would have the opportunity to present news related to his field of study and show for example, the innovative methods he uses in teaching. In practice, thanks to the workload of pedagogues, it is a common phenomenon that colleagues from the field within the school do not have an overview of what material and in what sequence others teach, which can lead to a contradiction in interpretation in other subjects, the omission of some important aspects or, on the contrary, excessive duplication of teaching. It should be noted here that adequate duplication is never harmful in connection with and minor refreshing of the material, on the contrary, it has a very favourable effect on the integration of information and its absorption by the student.

b) Substitutability

In the field of vocational education, it is often the case that there is only one specialist at the school for a given issue, who protects the focus, which in some situations can cause unwanted problems. To a certain extent, the issue mentioned in point a) is also related to this, which is also of great importance from the point of view of situations where a teacher needs to be temporarily substituted or fully replaced. A successful vocational education system should also remember such situations. **It is therefore necessary that at least a pair of teachers be created for each subject who would be able to substitute the missing teacher and teach the subject in an equivalent manner.** This approach sufficiently eliminates cracks in the profile of the graduate in cases where the teacher of a professional subject is indisposed for a longer period or in the case of the need for his permanent replacement.

c) Topicality

A big problem that professional education in the field of CNC woodworking often faces is the obsolescence of the information provided. It is based on a survey among students created as part of this ERASMUS+ project. **For this purpose, it is advisable for every teacher to visit at least once a year a fair or a conference covering the subject of the expert teacher's focus**.

d) Practical base

Another problem that students often mention in surveys is the lack of practical experience of educators, which is related to the previous point, but the causes of this problem are much deeper and there are more. Very often, students observe the symptoms of the so-called burnout syndrome in the teachers of professional subjects, which manifests itself in the teacher's feelings of futility and results in a reluctance to further develop teaching methods or their own development. It is known from many researches that the teaching professions are most at risk of burnout in the long term (Maslach, Schaufeli, a Leiter 2001; Katz et al. 2016). Teachers of professional subjects are the most at risk (Kinnunen, Parkatti, a Rasku 1994). This is due to the high demands for continuous personal development in the field and the insufficient feeling of satisfaction on the part of the students. The biggest problem for teachers of professional subjects is the absence of the result of their work, since no material result can be seen behind them. In addition, the student rarely gives positive feedback to the teacher, but negative feedback almost always reaches him. This is also why up to 50% of teachers stop teaching within the first year (Skaalvik a Skaalvik 2011). According to Finnish scientists, many of these problems can be solved by putting more emphasis on the inclusion of practical projects in teaching. The inclusion of teachers of professional subjects in practical activities is also, according to observations, very positive in many ways. The teacher gains greater self-confidence that he is not only a theoretician, broadens his view of the issue and thus increases the interaction with his colleagues, who are practically oriented. **Ideally, therefore, every teacher of theoretically oriented professional subjects should participate in at least one practical project per year.** As a practical project, it can be managing a graduation thesis, helping with the production of a contract in workshops or improving the school's itinerary.

2. Literature

Without a doubt, study materials are a very important factor for the correct and effective teaching of professional subjects in the field of CNC woodworking technologies. Unfortunately, this is currently an area that is completely lacking. Only specialist textbooks are available, where the keyword CNC is completely missing, or a small chapter is devoted to it regarding the existence of such a field. Such textbooks are more than 20 years old. Also, it can be found a lot of literature that is focused on CNC metalworking machines, where only common programming principles can be grasped, which is information worth mentioning. However, today's machines already work in programs with parametric programming, so it is more about setting than programming itself. But what the student really needs is a brief textbook aimed directly at woodworking machines, where

Co-funded by the Erasmus+ Programme of the European Union

the issue will be explained from a practical point of view. Therefore, we identify the basic parameters of suitable literature as **"Specialization", "Overall conciseness", "Topicality" and "Accessibility"**.

a) Specialization

In the first place, the content of the literature should correspond to the type of school according to the level (secondary/tertiary education). At the same time, the division of the literature should reflect the division in the thematic plan of the subject for easier orientation of the student and the teacher. It is very important for the literature in the field of CNC machining not to refer to CNC technologies in general, but to directly target those CNC technologies that can be encountered in the field of woodworking. **For a better orientation in terms, it is ideal if there is also an explanatory dictionary of terms, as CNC technologies contain many new forms that often need to be practically explained with an example, possibly accompanied by graphics.**

b) Overall conciseness

Study literature should appropriately supplement and expand the material discussed during classes. Therefore, it should not contain unnecessarily extensive knowledge in which the student could get lost during his studies. Currently, such literature is only wishful thinking, as there are only a few publications in the field of CNC woodworking, in which most of the space is devoted to the principle of programming CNC machines in the days when the code was written manually, which seems very incomprehensible for today's age of CAM programs.

c) Topicality

One of the biggest problems in the current education of vocational subjects is, after the lack of textbooks for woodworking disciplines, their out-of-datedness. Most of the textbooks that are available are just new reprints of more than twenty years old materials and the information in them comes from even older times. The novelty of the information provided by these specialist textbooks cannot therefore be said to be new. The teacher, as well as the student of these fields, is thus dependent on information from the Internet, which places an excessive time burden on both participants in the educational process. **The situation is worst in the areas of woodworking machinery and tools, furniture production technology, furniture constructions, woodworking CNC technology and furniture production planning.** Especially for this reason, this methodology also includes teaching material that straightens out the situation in the field of CNC technology, where the situation is the worst ever.

d) Accessibility

An important aspect for the correct teaching of the theory is, as has been emphasized several times in the study literature. It is essential if it is available to students. **It is ideal for today's time when the maximum amount of literature is accessible on school websites online, so that students and teachers have materials available at any time and immediately.** The material created together with this document under the name CNCcyclopedia will be available on the **websites of the partner schools of the project**.

3. Prerequisite of knowledge

a) Solid wood structure and mechanical properties

Co-funded by the Erasmus+ Programme of the European Union

When machining wood on a CNC, it is essential to have a deeper knowledge of the anatomy of solid wood from the point of view of its machining. During the machining of solid wood, the result is greatly influenced by the type of wood being machined, but also by the machining direction (perpendicular to the grain, along the grain). All variations in solid wood will affect the result from the point of view of surface roughness, deflection of the fibres on the edge. If the student knows the structure of wood well, he can better understand its machining on the CNC and better set up the machining, and possibly also choose the right tool. **Therefore, the student should also know well the mechanical properties of the grown wood, such as hardness, density, toughness, strength, flexibility, homogeneity, anisotropy, or thermal and moisture properties.** With these properties, the student should subsequently be able to explain some phenomena and principles during CNC machining, which leads to perfect final products without the need for further adjustments.

b) Wood based materials

Wood-based materials and their mechanical-physical properties, as well as knowledge of the properties of grown wood, are an important prerequisite for complex CNC machining skills. It is necessary to explain to the students what properties the material has and what consequences this may have during machining or how these properties will affect the choice of tool. **In this regard, properties such as hardness, density, toughness, strength, elasticity, homogeneity, an/isotropy or thermal and moisture properties play a role.**

c) Machine parts

Just like the previously mentioned theoretical specialist subjects, machine parts also belong to very important knowledge. If the graduate knows how the mechanisms used in CNC work, he will be better able to distinguish between high-quality machines and low-quality machines, and he will also be able to better define his requirements for the design of the machine, for example when buying CNC technology. For example, a graduate should be able to practically assess which mechanism is more suitable for a given machine and why. For these reasons, it is highly desirable that even such subjects be more focused on CNC technologies than is the case in most cases so far. **Students should be introduced in more detail to the types of CNC machine construction, types of linear guides, methods of position measurement, components related to workpiece clamping, tool changes, transmissions and drives of CNC machines.**

d) Woodworking tools

In the case of tools, targeting CNC technology is essential. Since CNC machines are highly complex and it would be difficult to find a type of tool that can be implemented in CNC, more emphasis must also be placed on modern computer-controlled technologies in such focused subjects. CNC machines often have much greater requirements for precision and high performance, which is why tool equipment also has its own specifics and a wide range of types. If we look only at the types of tool materials, they will give information on a separate subject. The tool is also closely related to the type of material to be machined, and there are principles on how to choose the right tools. **Therefore, topics such as tool tables, tool materials, tool geometry, tool sharpening, tool clamping, spiral milling cutters, milling cutters with exchangeable edges, CNC drills, CNC aggregates, grinding tools or edge banding tools should not be missing in the subjects devoted to tools.**

e) Machining theory

Co-funded by the Erasmus+ Programme of the European Union

The theory of woodworking loosely follows and complements the above subjects. Correct machining settings are the alpha and omega of CNC woodworking. This is because CNC machines have high performance and great emphasis is placed on the degree of production completion and accuracy. This also requires the correct setting of the machine and the cutting conditions. **The most important topics for CNC woodworking in such subjects are tool materials and coatings, cutting speed of rotary machining, feed rate, feed per tooth, chip thickness, machining sequence, choice of conditions for growing wood, choice of conditions for agglomerated materials, choice of conditions for composite materials, entry into the material, selection of the start of machining, machining in corners, energetics of machining.**

Co-funded by the Erasmus+ Programme of the European Union

Pillar II: Product construction – data preparation

This pillar includes the practical basis of production preparation, which is the alpha and omega of CNC production for a properly functioning operation. Although a properly prepared student would not be able to do without the other pillars, this part of technical education is certainly the most essential, the most comprehensive and the most demanding part of teaching, which applies with double emphasis to CNC technologies. The knowledge, and especially the practical skills, that the student acquires in this section serve as a solid foundation for the entire issue of furniture and wooden constructions production, from the design proposal to the construction solution, to the simulation of production. As the issues in this pillar are very comprehensive and usually intertwine with all years of vocational schools, they place great demands not only on the students themselves, but also on the school's equipment and the teaching staff.

1. Educational equipment

a) *Hardware*

Currently, there are constantly increasing demands on computer hardware equipment, especially around computer processor performance and operating memory. This is due to the demands of the software, especially for 3D design, modelling, and production simulation. For these reasons, it is important to continuously change the hardware equipment so that the students each have their own computer capable of meeting these ever-increasing demands without any problems. Furthermore, students should be able to use school computers outside of class time to complete homework and term papers. The following model and principles are proposed.

Computers for working in 2D should be equipped with at least a **processor with four physical cores** with a frequency of **at least 1.6 GHz** with **integrated graphics** with an accessible memory of **at least 4 GB** and a **frequency of at least 1.1 GHz**. The **minimum operating memory** of the computer should be **8 GB of RAM**. The optimal parameters are the same as the minimum parameters for working in 3D space.

For work in **3D space and rendering**, the minimum requirements must be increased, as the software for 3D operations requires a higher number of calculations per unit of time. The computer **processor** should be equipped with **at least four physical cores** and a **frequency of at least 2.9 GHz** with **integrated graphics** with an accessible memory of **at least 8 GB** and a **frequency of at least 1.1 GHz.** The minimum **operating memory** of the computer should be **16 GB RAM**.

Optimal parameters for working in 3D are intended for complex designs, rendering and 5-axis operations in CAM. The computer processor should be equipped with **at least eight physical cores and a frequency of at least 3.6 GHz** with a **dedicated graphics** card with a memory of **at least 4 GB of RAM and a frequency of at least 1.1 GHz**. The **operating memory** of the computer should be **at least 16 GB RAM**.

The number of computers in one classroom should not properly depend on the size of the classroom, but on the number of students in the scheduled groups, which **should not exceed 15 students in an optimal state**. This is the only way to effectively teach subjects focused on CAD and CAM. A larger number of students would mean the necessity of the presence of two simultaneous

Co-funded by the Erasmus+ Programme of the European Union

pedagogues to be able to pay enough attention to everyone during the training. Of course, the number of PC stations in one classroom can be larger for other needs of the school, such as seminars and training, or for the purpose of independent work of students on their assignments, but also as a reserve in case of a malfunction of one of the computers during classes.

For students to work independently on homework and term papers, it is necessary to set aside **at least one classroom or study room** where students can work on term papers or catch up on work they missed in class or because of being absent from class. However, it is crucial that these computers are equipped with all the software that students need to use during classes and homework. These are mostly difficult-to-access software such as Autodesk products or specialized CAM software, etc. Apart from the poorer availability of these programs, it is also necessary to consider the potentially difficult situation of some students who, due to their socio-economic situation, do not have their own computer with sufficient parameters to enable them such demanding software worked properly, although a freely available student version may be available. The classroom and study room should be **available every working day even after regular teaching hours, ideally from 7:00 a.m. to 6:00 p.m. The number of computers in the study room with this mode should cover at least one tenth of all students who work in specialized CAD/CAM software**. In the field of woodworking, such software can be Autocad, Alphacam, Sema, Dietrich's, Imos, Cabinet Vision, SolidWorks, Top Solid, Připravto, Turbocad or workshop CAM software from CNC manufacturers (Maestro, WoodWop, BiesseWorks, B-solid, F4 Integrate and next).

b) Software

For teaching to be effective, it is necessary for the school to have appropriate software. However, the problem in some cases is how to objectively determine which software on the market is the right one in which the teaching should take place. There are two basic approaches to this issue. In some schools, they teach students to work in as many programs as possible so that students have a broad perspective. However, the disadvantage of this approach is a very low level of deeper knowledge and acquisition of routine actions. Thus, the student knows the environment of many programs, but in practice he must go through a long path of training to be able to work effectively in any program. The approach also places high demands on program licensing and educator training in many programs. This approach is therefore rather suitable for the field of higher education, where a broad-spectrum view of the graduate is assumed without the need for deeper practical skills.

The second and rather more appropriate approach for secondary and higher vocational schools is to target a smaller amount of software with deeper practical skills. The question is, however, the right choice of program. For this purpose, cooperation and communication with the commercial sphere and associations, or clusters, are ideal, through which research can be done, which will show which programs the graduate is most likely to encounter, and these programs can also be taught. **It is advisable to carry out the survey ideally once every five years** (not more often) and adjust the curriculum and software equipment according to the results. Fewer changes in taught programs lead to lower requirements and costs for retraining educators and software licensing, and this further leads to higher quality and deeper practical teaching.

- *2D CAD drawing*

2D CAD drawing is the first level of technical production preparation that a student normally encounters. The most frequently used software in practice in this area is Autocad, which, due to its

Co-funded by the Erasmus+ Programme of the European Union

complexity and universality, is one of the indispensable software in which a student should be able to work. 2D CAD should handle the creation of basic geometry such as line, quadrilateral, circle, or polygon to create basic simple geometry. The software should also allow a basic palette of geometry modifications (move, copy, mirror, rotate, combine geometry into a curve, preferably also offset or trim/extend. Support for dimensioning and text insertion is also important. For further conversions and compatibility purposes, CAD should the program supports the basic drawing formats DWG, DXF and PDF. Most 2D CAD programs also support 3D CAD modelling, and therefore a whole range of input and output formats are supported, but the problem is often with the compatibility of some functions. The basic purpose of using 2D CAD programs is teaching creation of the drawing part of production documentation (DWG and PDF formats) as well as the basis for CAM software for simple products according to 2D geometry (DXF format). For more complex products and corpus furniture, it is more advantageous to use 3D CAD modelling or specialized CAD/CAM software.

- *3D CAD modelling*

3D CAD modelling is an imaginary second level of skills in preparing production for CNC operation. In the field of 3D modelling, there are many programs on the market that can work either parametrically or semi-parametrically. The specifics of the first variant are the clean input of dimension values without immediate graphic display. The graphic is displayed here only after entering the parameters or by forcing it to be generated. Often, this variant is used for products with a simpler shape and repetitive typified elements, for example, trusses (SEMA, Dietrich's) or cabinet furniture (Cabinet vision, Top Solid, Imos, Blum editor, Připravto). Freehand drawing in these programs is usually not user-friendly, sometimes not even possible. In the case of programs based on semi-parametric entry, free drawing and modelling is more user-friendly and mostly uses a system of selecting working planes. It is mainly used for modelling atypical shapes with more complex geometry (Autocad, Alphacam). The geometry is already visible during its generation and either coordinates in space or geometric parameters are entered. For proper profiling, the student needs to be taught both types of programs. The ideal combination is teaching Autocad, which is widely used in practice, with another program that is also compatible with CAM software and CNC.

- *CAM software*

CAM software is a program in which toolpaths for all types of machining are created from geometric data (2D, 3D, geometry, surfaces, solids) with the appropriate setting of cutting conditions. This software is therefore an integral part of production preparation, where the machining process can be designed, set, and simulated in advance, depending on the program. Most of today's CAM programs are also connected to CAD, so it is CAD/CAM software. In practice, two types of CAM software are distinguished in this area. The first are the programs supplied by CNC machine manufacturers with the purchased CNC machine - the so-called workshop programs. The second type are independent programs that can be purchased separately and therefore it is possible to work on them even without the need to purchase a CNC machine. Independent programs can be further divided into universal and specialized CAM programs for a given type of production - for example, cabinet furniture, windows, doors, or stairs. If the school does not have the facilities or funds to purchase its own CNC, it is possible, although not an ideal situation, to teach students to prepare for production on fictitious machines, which are usually implicitly embedded in independent programs for the purpose of simulation. It is advisable to purchase at least one independent program even if workshop software is also supplied with the purchased CNC, as these programs usually provide a wider and more universal range of functions for

Co-funded by the Erasmus+ Programme of the European Union

machining. Here, however, it is very important to simultaneously acquire an adequate post-processor for the given machine, without which it would not be possible to produce on a CNC from a universal CAM. The most ideal situation is therefore the acquisition of a CNC machine, which in the case of renowned manufacturers has built-in workshop CAD/CAM software, but this is not the rule. In addition to this machine, based on the type and purpose of the machine, also purchase independent universal or specialized CAD/CAM software with a license for a post processor created for the given machine model.

The basic requirements for CAD/CAM programs are import of 2D geometry from DXF and DWG import of bodies and surfaces from standard formats (DWG, IGES, STEP, etc.), creation of 2D or 3D geometry, setting of drilling machining, general milling, pocket milling, saw cutting and 3D milling in three to five axes, working with a tool database, 2D, ideally 3D machining simulation. Other useful features that are a great advantage for teaching are working with forging libraries, creating, and inserting macro commands, creating, and editing 3D surfaces and solids, parametric programming, saving machining styles, creating cut plans, generating barcode labels and more.

- *Server/Cloud storage*

To make working with data simple and efficient, it's ideal to provide students with some form of cloud or network storage that they can connect to from any school computer, and ideally after logging in from home. Such repositories subsequently eliminate many potential problems for students, such as the different up-to-datedness of one file on multiple repositories (for example, the disk of one's own computer, USB memory). Very often, a situation occurs with students when the student forgets to bring the carrier with the files in progress to the lesson, and thus does a large part of the work several times. It is also common to lose or damage a USB memory stick with files in progress. The advantage of working in CAD and CAM is that the output files are relatively small and therefore do not take up much storage space. This is especially important when each student has their own cloud mailbox set up, so that there are no situations where the folder of one of the students is accidentally or intentionally deleted. In such a case, the student must redo the work. The advantage of individual cloud boxes is also that it is possible to allow access to selected users and assign different permissions to different users, so the teacher could check the progress of the students' work and, if necessary, upload files individually.

- *Licensing*

It is very important that all software can be installed on many computers in classrooms and study rooms. The number of licenses to work in the program should be such that each student can always work independently. The number of students per teacher when teaching CAM should not exceed 15, as in the case of CAD software. The number of licenses should therefore be based on the number of students in one group and the number of classrooms where the teaching will take place. It can be considered ideal if a supplier of CAD/CAM software can provide students with an educational version that can be installed directly on their personal computers. In the case of a postprocessor, one or two separate licenses are more than enough since the generation of prepared and simulated data can always be carried out before the actual machining.

- *Topicality*

From the point of view of the need for up-to-date information, it is very important to set an update interval for the CAD/CAM software in which the students work. Programs undergo constant development, and every year functions and options are added that make working with

Co-funded by the Erasmus+ Programme of the European Union

the software more efficient. The environment and the appearance of the programs also change, which with a large gap of time in the order of years, i.e., skipping many upgrades to a new version, results in poor orientation in the program environment. The greater the distance, the more difficult it is for the user to adapt to the new version.

2. Human resources

a) Specialization

The complexity of the entire field of CNC wood processing also places high demands on the quality of teachers and the breadth of their scope. A quality pedagogue who can explain the material to the audience in a comprehensible way is essential for effective teaching. Due to the complexity, success in teaching CNC technologies can be achieved in two basic directions.

The first approach is to have a teaching staff composed of several narrowly focused pedagogues, i.e., to divide individual related subjects among a larger number of pedagogues. From the point of view of many years of experience, this is a less suitable solution, even though it is manageable at first glance. The biggest pitfalls of this solution are the extreme demands on communication between teachers of individual subjects. In practice, communication is very difficult to master, and even in the case when it happens in a good way, successful education is not guaranteed. You may then come across a time mismatch for individual subjects due to a class being cancelled for various reasons. At the same time, the continuity of individual related subjects is what makes the entire teaching process more efficient. Another major pitfall is the problem of substituted classes, when one teacher is replaced by another who may not be as proficient in the substituted subject, which reduces the quality of the concept. In extreme cases, which are unfortunately mostly represented across all such focused schools, communication between teachers of related subjects is almost zero. This leads to a paradoxical situation where one teacher tries to supplement the second and third and vice versa, and the students thus receive similar information over and over, but do not move forward as needed. It can be demonstrated on a sample situation where a student is faced with a pressing lack of time to draw production drawings in CAD, which is often assigned in several subjects (construction carpentry, furniture construction, CAD/CAM applied computing). The result is supposed to be practice and application of construction details, but the result is repetition of the same skill in multiple subjects. A huge disadvantage of this approach is the concentration of students in large groups (more than 10 students in a computer technology class or in practical training class). This approach is therefore less suitable from the point of view of acquiring practical skills in CNC production, as there is no smooth chaining of knowledge up to the final product. It may be more appropriate if it is only theoretical teaching with minimal emphasis on practice.

The second approach is somewhat the opposite, as it assumes broad-based pedagogues who teach smaller groups of students with whom a greater number of subjects are taught (for furniture disciplines, for example: furniture construction, CAD/CAM, up to practice). The teaching of related subjects is therefore rather divided into areas, which places high demands on educators, who must master the broader areas of CNC woodworking technology comprehensively, and there may be a shortage of them at first. However, this complication is multiplied many times over by a large group of advantages.

If we look at the second model in more detail, its premise is a smaller group of students, which is the most important aspect for the process of teaching CNC technologies from a practical point of view, since all students in the group can take turns in all practical tasks. In addition, a

Co-funded by the Erasmus+ Programme of the European Union

more individualized approach can be used in CAD/CAM subjects, which can better eliminate the different levels of education and skills of students. The concept also assumes that it is easier to maintain the continuity of the material discussed in individual subjects, which further leads to the elimination of duplicate requirements for the student, which allows the necessary time capacity to be obtained. In this way, it is easier to create thematic plans that follow on within the areas, and the student thus more easily perceives the issue comprehensively, which in practice leads to more effective learning directly during the lesson in three steps, i.e., **explain, demonstrate (prove), try out (learn)**. Thanks to this approach, the high degree of dependence of the quality of the graduate on communication between pedagogues is eliminated, which of course does not mean that communication between pedagogues is not beneficial - it always is. The side effects of this model are mainly an increase in the self-confidence of pedagogues, because thanks to comprehensive knowledge and skills, they are no longer viewed as unprofessional people with an absence of practice, which is one of the most frequently mentioned reasons for burnout (Truch 1980).

b) Substitutability

The issue described in paragraph a) is also linked to the issue of the replaceability of teachers. Again, this issue can be viewed from several angles. A teacher needs a short-term replacement during the current school year if, for example, he falls ill. In such a case, it is necessary to have an adequate substitute for him who can convey the prepared information to the students. However, such a substitute teacher should have at least basic knowledge of the given area. The ideal situation, however, is a full replacement by a colleague who teaches the same subject area in parallel.

A much greater emphasis on the need for pedagogues teaching in parallel is in the case of a long-term absence of the pedagogue, for example due to going on maternity or parental leave, or even ending the employment relationship. In such cases, there is a huge risk that the entire teaching of the area will collapse, and an adequate replacement may take several years. The greatest risk is in narrowly specialized fields such as CNC woodworking technology and related subjects. **For this reason, it is almost essential that each school has at least two pedagogues teaching in parallel in the field of CNC technology**.

c) Topicality

If a graduate is to master the issue of CNC woodworking, the most important prerequisite is a quality teacher who not only manages the issue himself but is able to convey it effectively. This is only possible if the teacher has deep and **up-to-date** theoretical knowledge, but mainly practical skills. As in the case of the profile of the graduate, it is also necessary to establish the ideal profile of the educator for the teaching of CNC woodworking technologies for the entire teaching concept. The concept envisages the division of teaching into areas where the teacher must manage issues from production preparation to final production. **It is therefore mainly about the subjects Furniture construction and/or Construction of construction and joinery products, CAD 2D + 3D, CAM, tools for CNC, parts of machines in CNC technologies, practical production on CNC. At the same time, the teacher must be equipped with at least basic knowledge of other related issues, such as woodworking technology, wood-based materials, and their physical and mechanical properties.** Ideally, the teacher should be able to master all the forementioned knowledge, but it is not necessary for him to teach all of them, as it is impossible due to time constraints. Therefore, the areas described above should be determined for the given teacher. In the described areas, however, there should be continuous self-education of the pedagogue, which can be ensured in several ways.

Co-funded by the Erasmus+ Programme of the European Union

To keep the imparted knowledge and skills up to date, there is a need for continuous development of the educator, who should maintain contacts both with users of CNC technology and with its manufacturers. This can be solved in the basic mode with seminars, internships, or excursions. From this point of view, cooperation on external projects or contracts has a much better impact. Cooperation on real projects with partner schools or commercial institutions usually leads to constant practice of the pedagogue's skills, new problems and situations are often solved, which from the pedagogue's point of view not only improves and trains his current expertise, but also brings him higher self-confidence, which is positively reflected in in the approach to his teaching. Here, however, attention must be paid to the time aspect, so as not to overload the teacher with projects and orders, as such a situation would lead to the opposite effect due to the teacher's stress. **Therefore, the right choice of measure is important**. Another very favourable effect is the influence of international cooperation, for which a special chapter is reserved in the methodology. Cooperation with foreign institutions can take many forms, and all of them have a positive effect on the up-to-date knowledge of educators, as it can bring innovative elements and previously overlooked knowledge to teaching.

d) Practically oriented

As mentioned above, the practical skills of a teacher who teaches CNC technology are essential, on two levels. Passing on current practical knowledge in the field, but also personal development and the feeling of tangible results of the teacher. If the teacher lacks practical skills and only imparts theoretical knowledge, in most cases such an approach leads to ineffective teaching, when the teacher does not always have to focus on essential topics, low status on the part of the students, all of which can lead to early burnout syndrome. For these reasons, it is of great benefit if the teacher participates in real, albeit less demanding projects/assignments, as described in Pillar I:1.d). In the case of practically focused projects, the simplest option is offered in the form of assigning and managing grade and graduation theses, where the teacher will always encounter real production. However, participation in external contracts and projects is also a great benefit, where there are usually further shifts of the pedagogue in many directions.

3. Course of action

a) 2D drawing in CAD

The first subject where the teacher should practically touch CNC technology is drawing in CAD 2D. It is important that students start working in these programs no later than in the second semester after starting school and become familiar with the environment and the basic functions and principles of creation within one semester. In 2D drawing, students should firstly practice the principles of displaying drawings (views, sections, details), where the student will learn to draw production drawings, dimensioning and hatching. However, the principle of drawing is much more important for CNC production. As part of the subject, where students are introduced to CAD drawing for the first time, it is therefore necessary to introduce the students to the practical dimension of drawing, i.e., the effects of drawing on the later use of data (drawing direction, contour location, double line). If there is space in the course, it is advisable for students to demonstrate the export of the geometry to one of the CAM software on a simple outline, so that they can see how the errors will manifest themselves in the following steps. It also seems important to work on a real product that fits into the students' field of study.

In connection with the principles of drawing in CAD as a basis for the needs of CNC production, it is necessary to explain to students the basic principles and issues that differ from the drawing of production drawings, which are not the basis for CNC. It is mainly an issue of joining the contour, where it is necessary to distinguish between open and closed geometry in relation to tool compensation. Some CAM software can also have reading problems if overlapping geometries are joined, so students need to practice drawing so that multiple lines in the geometry do not overlap. Also, drawing splines is a common problem in manufacturing, and not all CAM software can work with splines, so it's better to avoid this kind of geometry or convert it to a classic curve. In this context, it is also necessary to instil to student methods of creating arcs, which can cause problems in CNC during production. Because it often happens that during the conversion from a spline curve to a classic curve, the number of segments is high, and each segment represents one separate line of code for the CNC. This causes the machine to machine such a radius very slowly and jerkily, which affects the quality of the machining and creates a problem in the form of inadequate setting of the cutting conditions of the tool, and the tool can act to burn the workpiece, in addition, it heats up and dulls faster. For these reasons, it is better to use the arc function, which works as a separate function and the tool works at a constant speed, as on straight points of the contour. There should be no contours in the drawing, or in the drawing level intended for CNC processing, that will not be machined. In practice, this means that all auxiliary or hidden contours, hatches and dimensions should be at a different level from the one that includes the machined contours or should not be in the drawing at all. The location of the contour in 2D space is also a very important aspect. The coordinates function as a map that subsequently guides the tool to the cut, and therefore the zero point on the drawing should correspond to the zero-starting point, which eliminates the need to move with the contour using an offset or offset from the starting point of the machine. Not all CAM programs, although it is standard today, are of the CAD/CAM type where at least basic geometry adjustments can be made, which also acts as unnecessary downtime during data preparation.

b) 3D modelling in CAD

If teaching drawing in 2D is successful, modelling in CAD 3D is the next logical step. This step should immediately follow CAD 2D, i.e., it should be taught in the third semester of the field of study at the latest. In this regard, in addition to the skills related to design solutions and visualization, it is necessary to practically control the actions that are subsequently related to the transfer to CAM and the production of the modelled product on the CNC. In the first phase, it is crucial to familiarize students with the differences between 3D geometry, solids and shells and the consequences of individual variants for further work in CAM. The next stage of teaching must be the skills of modelling itself from simpler operations to more complex ones. The first stage in 3D should be the creation of basic solids (cube, cylinder, cone, pyramid, sphere, etc.) and their joining, subtraction, and difference. In the next phase, it is necessary to go through the extraction of the body or the shell (for non-closed geometry). For the next steps of 3D background creation, it is necessary to practice in detail the principles of working with drawing planes and editing in 3D (shifting, mirroring, rotating, dividing, rounding, bevelling, slanting, etc.) The last learning step should be advanced functions and actions for 3D modelling (dragging along a curve, templating, extruding with rotation). Again, it is very beneficial if the functions are demonstrated on real simple products, see point f).

c) Object transfer to CAM

In the case of successful drawing training in 2D and 3D CAD, data transfer to CAM is simple, but you cannot always count on perfect data preparation during drawing, so in practice you can very often encounter problems during conversion. Most of them have already been described

Co-funded by the Erasmus+ Programme of the European Union

above. Another pitfall is the diversity of CAD and CAM program compatibility, and not all CAM programs support all import formats. Therefore, it is also necessary to familiarize students with different types of basic formats of geometry, surfaces, and solids and to demonstrate the procedure by which different formats can be successfully converted into CAM, which often saves tens of hours of work. The most common formats are DWG, DXF, 3DXF, STEP, IGES or 3DS files.

d) Machining and simulation in CAM

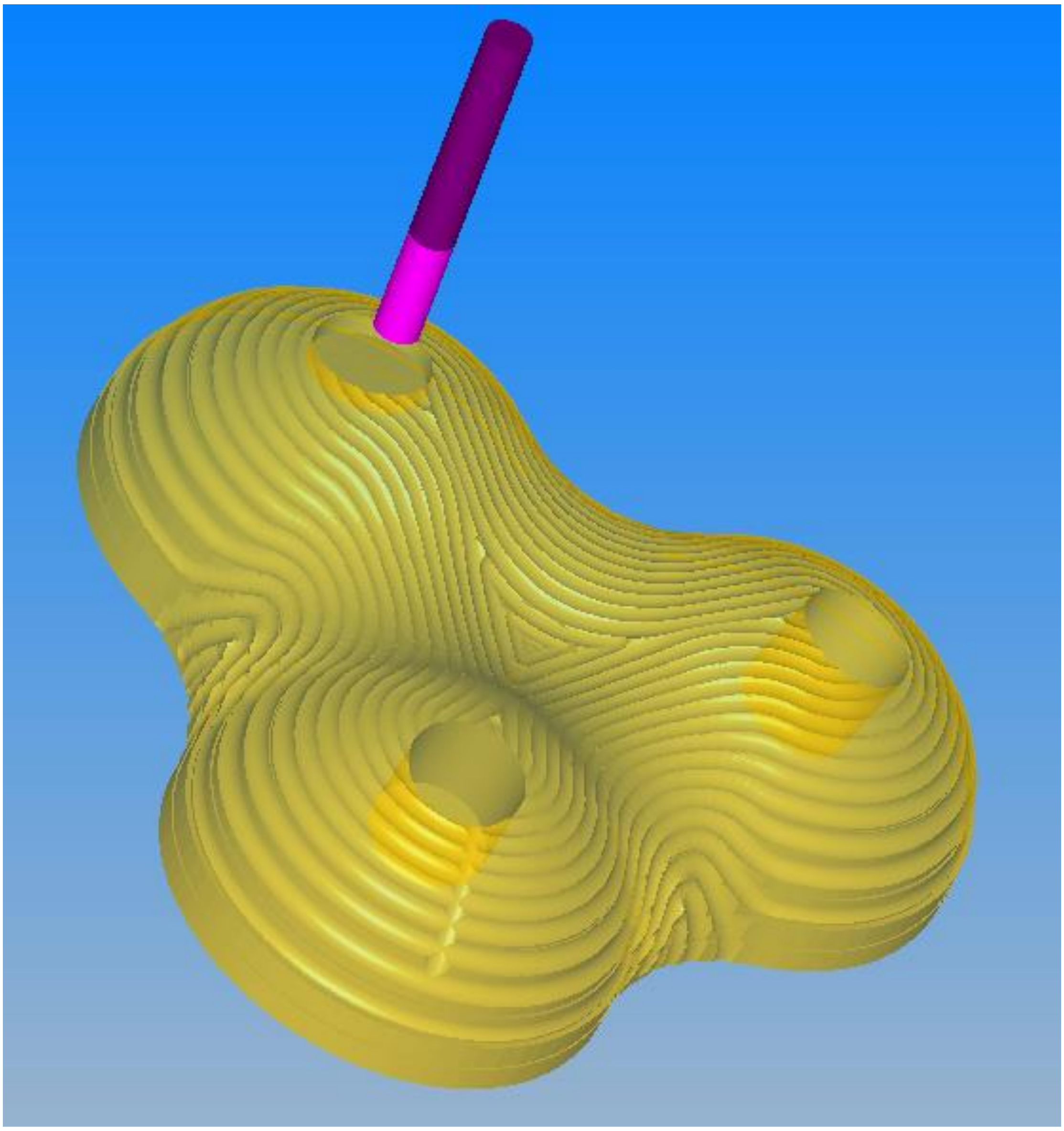
Although, in terms of our division, we are still moving in the part dealing with theory, the work in CAM is already more practically oriented. This is only evidenced by the fact that theory and practice are very closely connected at CNC and teaching one without the other does not become more important. In this part of the production, application is taking place, but not yet all the loaded theoretical knowledge has been verified. From the point of view of production preparation, the greatest emphasis should also be placed on this step, to which the hourly subsidy should also correspond. As there is a large amount of CAM software, it is difficult to determine the exact methodology of the teaching process, but as a framework, the following areas should not be missing in the teaching:

- **Basic familiarization with the CAM software environment and principles of creation**
- **Problems of importing geometry, surfaces, and solids, obtaining geometry from 3D objects**
- **Consistency and non-consistency in machining, types of milling tools, spiral cutters**
- **Roughing and finishing, proper tool selection, machine limits**
- **Geometry milling and pocketing, closed and open geometry, base plane tool compensation**
- **Drilling and gouging holes in the base plane**
- **Cutting with a saw blade in the base plane**
- **Principles of working with planes, creation of new working planes**
- **Milling operations, creating pockets and holes with automatic depth from a 3D solid**
- **Principles of 3-axis 3D milling**
- **Principles of 3D milling in 5 axes**
- **Tool management**
- **Final settings (operating commands, machining sequence, part offset, table setup)**
- **Nesting**
- **Post-processing**

e) *Example tasks for modelling*

Except tasks that are shown further below in category Pillar III:3.i), there are some more tasks which can practise higher level skills of modelling in CAD or preparing in CAM.

- *3D manufacturing (here applied on design stool seat level 4/5)*

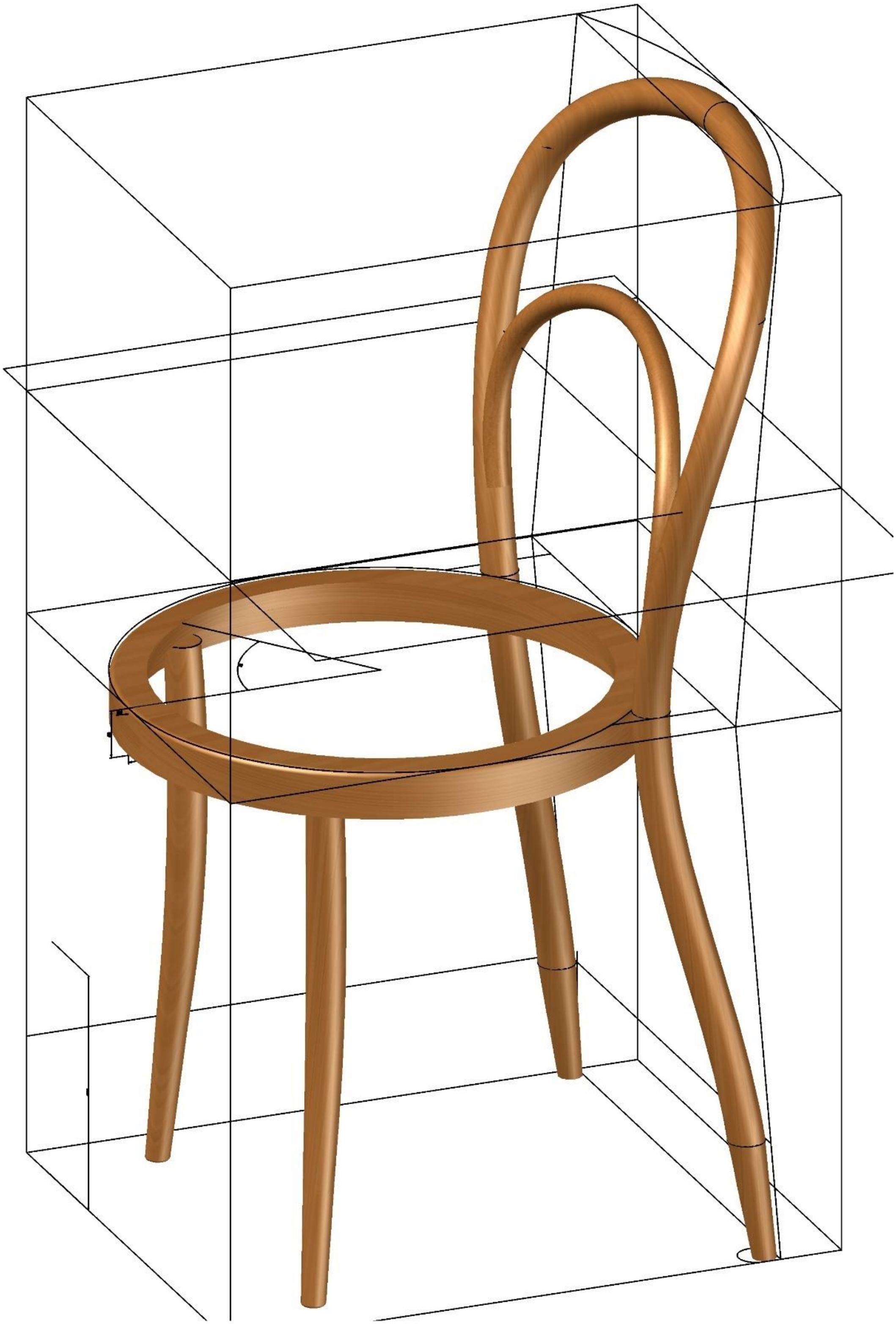


Co-funded by the Erasmus+ Programme of the European Union

- *Dinning chair replica (level 4/5)*

Co-funded by the Erasmus+ Programme of the European Union

- *Bentwood chair replica (level 5/5)*



Co-funded by the Erasmus+ Programme of the European Union

Pillar III: Practical training on CNC

1. Machinery equipment

a) CNC machines

CNC machines are generally very demanding in terms of purchase price, space, technical connections, but also operating costs, and therefore there is no universal optimum in terms of teaching. Small "garage" CNCs are also available on the market, which can be purchased cheaper, and the principle of function can be explained on them. Therefore, if the school does not have the resources, it is possible to teach in this way, however, it will not prepare the students as well for the real operation that awaits them at work. Therefore, if funds are or can be obtained thanks to school development projects or as support from the state, it is very important to take advantage of any opportunity and purchase the most modern equipment, which today does not have to be demanding on the necessary space thanks to semi-vertical CNC machines.

Each school that educates future experts in the field of woodworking has its strengths and weaknesses, for example a focus on wooden buildings, design models, furniture (solid or corpus), staircases or other construction carpentry products. These sites must be identified and considered from multiple perspectives before purchasing a CNC. If the school is focused on several fields and wants to develop them also in the field of CNC, it is necessary to realize that as the universality of the machine usually decreases, its functionality from the point of view of individual specializations decreases. Therefore, it is necessary to consider whether to purchase one universal machine or several narrowly focused machines. It can be stated on the current and very frequent dilemma of choosing the type of table (raster or beam). If the teaching is focused more on corpus furniture (for offices, kitchens, etc.), where you work mainly with board material, the clear choice today is a raster table, where you can also purchase a cheaper variant operating only in three axes. However, if the teaching is focused on the production of solid wood (chairs, tables, windows, doors, stairs), where 5 axes are needed, a table with beams (consoles) is more suitable, while the machine will not be as efficient for board materials, but it is also he can do it. But if the school is focused on all areas, the choice is already much more complicated. On the one hand, there are options for universal machines on the market that can handle everything, or you can resort to the solution of purchasing several machines (at once or spread over time). If there are funds and sufficient space in school workshops, it is always better to buy more machines with a lower degree of versatility. On the other hand, if there is no space, a universal machine is a better option from a financial and operational point of view, but it is necessary to consider that the operation of the machine (usually clamping the part and rebuilding) will be more demanding on the time and skills of the authorized operator.

Be very careful when purchasing the machine, it is necessary to pay attention to its quality and comprehensive delivery during the specification of the machine. Schools are usually at a disadvantage compared to commercial entities, as the lowest bid usually wins the competition, while the specification must not be discriminatory to others. In practice, this can mean a big problem, because in the case of meeting a specification that is not worked out in detail, a machine that ultimately does not fulfil the function that we would expect (for example, cheap machines from Asia) can win. This problem can only be solved by a detailed specification of technical parameters and needs for the school, to deliver a machine that will serve the intended purposes. It is necessary to remember the compatibility with the software that is taught, the operating system that is used at the school or the language of the environment. In no case is it recommended to

Co-funded by the Erasmus+ Programme of the European Union

purchase a machine without an appropriate license for CAD/CAM software, otherwise the overall functionality of the machine may be jeopardized, or it will be necessary to purchase additional licenses, which increases the total time of commissioning the machine. It is also very important to remember the specification of professional training on the machine for enough educators, warranty conditions including the specification of the speed of defect removal, service conditions and consulting services, which are extremely important, especially at the beginning of operation.

The ideal concept today is a system where the school can simultaneously accept contracts from outside and participate in projects of other schools to cover operating costs. In this way, students can see the production of real products and collaborate on it themselves, which over time turns out to be the most beneficial element of production. The purchase of the machine itself can thus benefit the school from a long-term point of view, even from a financial point of view, although performance cannot be expected, as in commercial enterprises. However, it is necessary to expect greater demands on the CNC operator and the professional teaching staff, **viz Pillar II:2**.

Before, during and after the process of purchasing a CNC machine, it is necessary to sufficiently think through the concept of operation and include all sides of the input (teaching, student works, orders). After purchasing the machine, all three activities tend to overcharge each other, and it is necessary to set up such a system so that they are in an effective balance. In practice, it is a common phenomenon that external orders and projects represent time pressure on the production date and tend to push other activities into the background. This ultimately goes against the purpose for which the machine was purchased - the education and practice of students. For this reason, it is necessary to test the strategy and set the operating mode during the first year of operation of the machine.

Since education and its support depend on the priorities of the government's program statement and its fulfilment, it is necessary to have ready various alternatives for the purchase of machines and their detailed technical specification, which can be used when the right opportunity comes (subsidy program, project call). Without high-quality technical equipment, the teaching of practically oriented fields will always be only theory, and with the increasing technological level, you cannot rely on short training by the employer, as he already needs staff with knowledge and skills, while the old practice model in companies no longer works, **see** Error! Reference source not found.. For these reasons, the acquisition of equipment should be the number one priority even at the cost of eliminating older machines in workshop machine rooms.

b) Tooling

A common problem at schools is the acquisition of a CNC without tools, which need to be purchased in addition, or a basic set of tools and clamps is delivered, in which no further investment is made. This further limit the development of the field at the school both in the form of stagnation of teachers and students and their projects. Equipping CNC tools is one of the important steps to effective teaching, as there are many solutions on the market that need to be known in both production and teaching. If the CNC has a drilling unit, it is advisable to equip it with such drills, which can be used to drill holes for basic structural machining of body panels **(pins, confirmates, eccentrics, cabineo, shelf supports)**, but also, for example, **countersinks** or drills for marking the position of screws in fittings (through drill). For the main spindle, you need to look not only at the number of tool positions in the magazine, but rather at the nature of the projects and jobs that the machine performs. Students need to be introduced to as many technologies as possible and practically demonstrate to them the consequences of the wrong choice of tool and comparing tools. For effective teaching, it is necessary to have at least the following tools for the

Co-funded by the Erasmus+ Programme of the European Union

main spindle: **roughing spiral cutters of five different diameters, finishing spiral cutters of two different diameters, mortise cutter of two diameters, ball cutter of two different diameters, conical engraving cutter of two different angles, folding cutter, comparison cutter, diamond finishing cutter, chamfering and rounding cutter, two diameters of universal saw blades if the machine operates with saw blades, a special nesting cutter for nesting machines**. More creative projects and orders, which leads to the further development of professional education in this area.

Already when specifying the CNC, for the reasons mentioned above, it is necessary to think about purchasing enough tools, collets, and clamping sleeves. It is then recommended to invest in the purchase of new tools in the amount of at least **EUR 1,500** each year to guarantee appropriate further development. Timely maintenance of existing tools (sharpening, blade replacement) is also a matter of course.

c) CNC holding fixtures

Another important aspect is the view from the clamping point of view, which is also related to the type of table that the CNC has. There are many lower CNC ranges on the market that have mechanical clamping of the workpiece, which is only suitable for modelling products, but to produce furniture, construction carpentry products or wooden structures, this solution is completely inappropriate and can rather discourage students due to the complexity of clamping. Vacuum, pneumatic or a combination of these two methods must be chosen for workpiece clamping. As with tools, it is essential that the school has enough clamping blocks (suction cups, clamps) or other clamping devices to ensure the widest possible range of possibilities during teaching and production. This item also needs to be considered when specifying the machine.

2. Human resources

Probably the biggest current problem, which also reflects the problem on the labour market in the field of CNC technology, is the lack, or rather the total absence, of qualified CNC machine experts who would also be good teachers. When buying a machine for a school, you need to remember this aspect as well, because a machine that no one knows how to operate will not bring anything to the school, only more worries. Therefore, it is necessary to secure competent teachers who have at least basic knowledge of the principles or practice on CNC machines. The problem of their lack is, on the one hand, that the lack of such focused people is troubling the entire labour market across Central Europe, and the conditions in education exacerbate the problem even further. Finding a person on the labour market who has even basic skills with CNC technologies is very difficult, finding someone who also has a pedagogical education is an almost impossible task. At present, however, a relatively large number of them are needed. Schools have no choice but to teach and operate CNC technology only marginally or even not at all. In the best case, there is one specialist at the school who has learned to work with CNC on his own, and usually only at a basic level. However, if the pedagogue is to teach the material effectively and in depth, it is necessary for him to master it himself. More than one teacher should participate in the teaching of CNC technologies, given the breadth of the topic.

a) Specialization

The focus of an educator teaching practical skills with a CNC machine should include comprehensive knowledge of CNC machines, but also production preparation in general. This is the assumption that the teacher will be able to work well with the CNC machine that the school has but will also be able to quickly switch to work on a machine that the school can purchase in the future. A quick basic training is often provided with the machine, and if the teacher is already familiar with other machines, he has no problem operating the new machine almost immediately. Unfortunately, the reality in schools is that workshop masters do not have experience working on a CNC machine, and rapid training is insufficient for them, as a lot of new information is imparted in a short time. This further leads to demotivation and an uncertain attitude of the teacher when handling the machine and a very long time before he starts passing on at least some information to the students. He subsequently improves himself by the "trial and error" method, which on the one hand leads to a very slow consolidation of skills with CNC and a very slow development of the field. Therefore, if the pedagogic corps of workshop masters is inexperienced in these technologies before the acquisition of CNC technology for the school, it is necessary to remember to invest in a larger number of shorter training sessions connected with production demonstrations on real products. Only in this way can it be achieved that the corps of pedagogues will develop properly without a demotivating effect. **Ideally, the school should have teachers who manage the entire CNC production process as well as production preparation**. In practice, however, it is often the case that some, mostly older masters, do not have in-depth training in working with computers. In this case, it is necessary to teach these educators only the practical part of production, i.e., **turning on and calibrating the machine, maintaining the machine, uploading the file to the machine, setting up the table and choosing the starting point, clamping the workpiece and starting the work cycle and checking it with the controller**. However, other educators who are specialized in CAD/CAM production preparation must also cooperate with these teachers so that there are no problems during teaching or production. For the teaching to be effective, it is ideal that there are not large groups of students at the CNC at the same time. **Based on experience, the optimal number is up to 5 students, a maximum of 10 students can be taught this way**. If there are more students at CNC during practical production, it cannot be expected that all of them will be able to work with the machine. A very beneficial factor in the case of practical training at CNC is the organization of a special interest group for students and teachers.

b) *Substitutability*

As in the case of production preparation teachers, practical teaching pedagogues must also be replaceable in case of a longer absence from teaching. A big risk is also the turnover of practice teachers with experience with CNC technologies, which are in short supply on the labour market. **For these reasons, it is essential that there are at least two people in the school workshops who can operate the CNC machine**. In the vast majority of schools in the partner countries of the project, there is always only one person in charge of CNC technology, which often causes problems in the event of his absence. In addition to the absence of instruction, this also creates problems with overworking this employee.

c) *Topicality*

Keeping knowledge up to date does not seem to be a big issue for CNC machining practical training educators, but it is important to constantly develop these employees to some extent. On the one hand, CNC machining technology is constantly evolving, where tools can be an example, but new workpiece clamping techniques and applicable technological procedures can also be sought, for example creating new types of joints or solving design challenges. For development, the concept of cooperation on external contracts is excellent, which often brings many complex situations, which means that pedagogues are always kept in the center of events in the field, the latest procedures and are constantly developing. This information is then directly and indirectly passed on to the students, thus creating an automatic cycle of development of the field at the

Co-funded by the Erasmus+ Programme of the European Union

school. In this context, a frequent problem in teaching is that, due to the lack of time, there is no space left to record different solutions to new challenges and procedures. Records of processes during CNC machining in any form are the most important prerequisite for the information to be disseminated further. Therefore, it is a great benefit if teachers operating at CNC are motivated to take continuous photo or video documentation. These record formats are excellent for the purpose of archiving and disseminating new knowledge and are also very close to the current generation of students. For this purpose, CNC machines can be equipped with a camera device that records the production process. To increase student interest, the school can also be equipped with an online feed to the screens in the corridors directly from the machine, which can run while the machine is working in real time.

d) Cooperation

An important aspect of the development of CNC machine operators in school workshops is cooperation with companies, but also with other schools at state or foreign level. In general, schools have the great advantage that companies can put them into production more easily than their competitors, and therefore it is necessary to use these possibilities for the permanent development of knowledge. Cooperation with companies where the school employs graduates is ideal. The experience of two-sided advice and consultation during the production of more complex orders is very useful. A very important aspect is also frequent communication with manufacturers and suppliers of CNC technologies and tools, who often deal with customers with various new solutions that do not normally reach schools. Finally, international cooperation with partner schools on their student or scientific projects is also beneficial. This cooperation is further described in Pillar IV: and **Error! Reference source not found.**. It is ideal to cooperate long-term w ith at least one supplier of CNC tools, one supplier of clamping technology and at least one company from each main area of woodworking (staircase production, window and door production, massive furniture production, kitchen production).

3. Course of action

a) Prerequisites for safe work and technical characteristics

The first topic of practical training should be work safety during the operation of the given CNC machine. During the introductory hours of practice on the CNC, the safety elements of the machine and their functions should be explained, i.e., **pressure mats, laser barriers, safety bumpers, safety ropes, safety door locks, motion sensors, photocells, screens against flying off cuttings, emergency buttons**. Further behaviour of the operator and students near the machine during machining, which should also be specified, depends on these elements.

The introductory part also includes specifications of the technical parameters of the machine, a description of basic components and functions, as well as requirements for technological and operating media. **The dimensions of the machine (installation, operation), floor load-bearing requirements, sawdust extraction performance, energy consumption, requirements for the quality and quantity of compressed air, maximum and minimum revolutions of the spindles, maximum weight and dimensional characteristics of the tools or methods of cooling the spindles should be explained**. Furthermore, in the introductory part, the issue of machine reference points, measuring the machine's position and the related method of machine reporting should be explained. The production possibilities of the given machine and its purpose depending on the typology of the machine and the type of table should also be mentioned.

Co-funded by the Erasmus+ Programme of the European Union

b) CNC maintenance and service

Another topic that needs to be discussed in detail with students regarding CNC machines is the maintenance system. Since CNC machines are very complex devices, properly performed maintenance prevents possible fatal consequences during machining, but also increases the service life of individual components and the correct functioning of the machine from the point of view of machining accuracy. It is better to go through this chapter not only in summary during the introductory part, but also to pay more attention to it during further work on the machine. The most important areas of this topic are maintenance of the spindle cooling system, vacuum clamping system, lubrication systems of moving parts (axes, reservoirs, spindles), cleaning operations (cleaning of the electro spindle, sensors, clamping cones, machine space), filter elements, visual - control operations, maintenance tool trays. Most modern machines include their own maintenance system, which prompts the operator to perform a given service task at set intervals. It is also necessary to familiarize students with these systems and their principle during the lesson and demonstrate practical maintenance.

c) Step by step procedure

To teach effectively, it is necessary to start active production on the machine as soon as possible during the year, during which the students will also master other activities. First, it is appropriate to slowly and clearly demonstrate to the students the process of working on the machine during machining step by step from turning on the machine, starting the control system, referencing the machine, uploading the program, setting up the work area (laying out the clamps) and starting the work cycle. First, it is advisable to start with easier tasks and proceed to more complex machining, see point i).

d) CNC tooling

One of the most important topics in CNC machines is tool management. As CNC machines are very versatile, they also include an abundance of types of tools with different properties, which students should, however, know from the subjects dedicated to this. As part of the practical training, however, it is necessary to teach the student the principles and procedures of the tool manager, which is an indispensable part of modern machines. The first area of tool management is the introduction and proper definition of a new tool. Again, it is necessary to start with easily defined tools, i.e., cylindrical cutters with a straight end, then it is possible to add spherical and conical cutters, and finally profile cutters. The student should be able to enter all necessary parameters of the tool. The correct insertion of the tool can be tested on most modern machines directly in the tool manager using a new set of tools so that the correct operation of the CNC is not jeopardized in case of student errors. The next phase that needs to be practiced with the students is physically putting the tool into the magazine and unloading the tool from the magazine. For the training to take place, it is necessary for the student to also be able to clamp the tool correctly in the case and explain the importance of using a torque wrench when tightening the nut. The student should measure the tool himself and enter the geometric parameters into the tool manager and based on the accumulated knowledge from other subjects, assign technological conditions to the tool, i.e., minimum, optimal and maximum number of revolutions and feed rate. If the machine has a probe for measuring the length of the tool, it is also necessary to convey this issue to the students, as it is already standard equipment these days.

e) CNC table set-up

Co-funded by the Erasmus+ Programme of the European Union

Equipping the workbench is the next stage in the production process. The real setup of the table is based on the virtual setup, which should be dealt with by a subject focused on the preparation of CAM production, where the table can be precisely prepared. The physical equipment can then take place in different ways depending on the CNC equipment, and the student should properly learn more ways to be universally prepared as a graduate. As part of equipping the work area, it is necessary to learn, if possible, the principle of attachment to the base plate, and/or the use of vacuum clamps in the grid of the table, and/or on the beam, and/or the use of pneumatic and/or vacuum clamps, and/or the use of vacuum clamps on base plate, and/or clamping the part on a rubber seal directly on the raster table. If it is necessary to position the clamping elements, it is also necessary to explain the multiple methods available on the machine, i.e., positioning using a cross laser, and/or colour LED indication, and/or using the coordinates on the controller and the present scale on the table axes. If clamped to a base plate, it is possible to teach students how to handle a projection laser. In connection with the clamping of the component, it is also necessary to clarify and demonstrate the issues of vacuum performance and clamping force, vacuum division of the table into zones, the establishment of zero points of defined stops and the principle of offset of components from the edge, i.e., clamping of the workpiece with an attachment (for example, for irregular shapes or clamping above the level of the stops). Also very important is the topic of offset and setting the height in the Z axis and setting the offset of the base plate or measuring it using a probe.

f) During the machining

The correct behaviour and habits of the CNC operator during machining can often avert many unpleasant situations because mistakes can always be made in the process of preparing the production for CNC. The CNC operator is therefore present at the machine mainly to check the machining. From the moment the program sequence is started, the CNC works in automatic mode, however, the operator can still influence many things with the controller. The controller is equipped with potentiometers (in some cases, one common for rapid traverse and for working speed, on some machines they are separate), with exceptions, it is ideal to reduce the working speed to a minimum and leave the rapid traverse at safely monitorable speeds. Especially when running a program for the first time, it is ideal to watch the tool enter the workpiece to make sure the depth is set correctly. Subsequently, it is necessary to set the working potentiometer to the ideal speed to avoid excessive heating of the tool or burning of the material. Also, in the case of nesting machining, the student in the role of operator needs to be taught the correct procedure during machining, which is distinguished by the high performance of the tool. Here, the rule is to check the height setting of the base plate at least twice before starting the program and not to monitor the approach by decelerating the potentiometer, to avoid burning the material and damaging the tool. Other actions that need to be covered during practical training on CNC machines are the following topics: procedure in case of machining failure (vacuum drop when part is released, tool breakage, tool jamming during replacement, collision of tool with clamps or stand).

g) Semi-individual work

In the following grades, it is advisable to start working on various tasks to cover as many possibilities as possible that the student may encounter in later employment. For this purpose, work on external contracts, which tend to be diverse, is very suitable. When completing tasks on contracts, it is necessary to assign occasional independent tasks to students, which are carried out (started) under the supervision of professional supervision.

Co-funded by the Erasmus+ Programme of the European Union

h) Individual student tasks

In the last year, the student should already be able to operate the machine independently at the discretion of the expert supervisor, as the level of all students is never the same. In such cases, the ideal situation is when the student works on his final project independently or in small groups and consults his procedures with professional supervision.

Co-funded by the
Erasmus+ Programme
of the European Union

i) Example tasks for manufacturing with level estimation

- *Plywood self-joint furniture (level 3/5)*

- *Key box (cabinet level 2/5)*

Co-funded by the
Erasmus+ Programme
of the European Union

- *Massive wood cabinet with frame doors (level 3/5)*

- *Classic stool (level 3/5)*

- *Learning tower for kids (level 4/5)*

Co-funded by the
Erasmus+ Programme
of the European Union

- *Cutting board with engraved logo (level 1/5)*

- *Smartphone stand (level 1/5)*

Co-funded by the
Erasmus+ Programme
of the European Union

- *Corner finger joined solid wood (level 4/5)*

- *Corner dove tail joint of solid wood (here aplied on table level 5/5)*

- *Wooden book (level 5/5)*

- *Special shapes (this is table for vicarage level 4/5)*

Co-funded by the Erasmus+ Programme of the European Union

- *Tenon and mortise joints (level 3/5)*

- *Office drawer cabinet (here connected to the table level 5/5)*

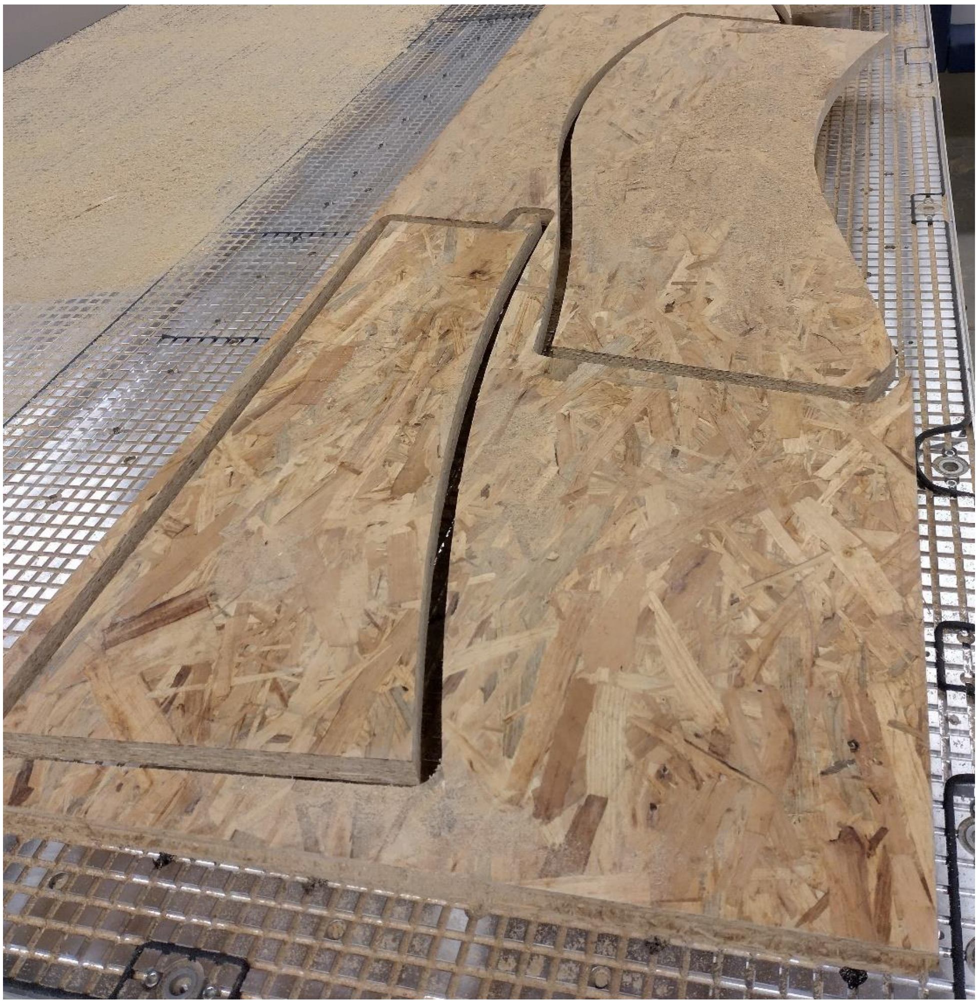
Co-funded by the Erasmus+ Programme of the European Union

- *Stair handle (level 5/5)*

- *Stair sides (level 3/5)*

- *Kitchen cabinet fitings possitioning (drawers, doors, etc. level 2/5)*

- *Nesting formating (level 2/5)*



Pillar IV: Industry collaboration

According to the survey among students, **"students do not feel often sufficiently prepared for the labour market"**. The lack of practical application of theoretical knowledge causes students to fear entering the labour market. Students have doubts about whether they can use the things they learn at school in practice. One of the possible answers to this problem is a higher connection between education and practice.

Connecting education with practice is not only about completing professional practice outside the teaching process. Working with practical examples or the presence of experts from practice in teaching process can help students better grasp the theoretical concepts of the studied area. Understanding these concepts can help them analyse and work with different situations that await them in practice. At the same time, the concretization of theoretical knowledge through practical examples to students according to their statements helps to stimulate their interest in the studied material. Together with the ability to meaningfully use theoretical frameworks in practical life, this can lead them to push the boundaries of knowledge in their area of professional expertise in the future. They can thus become active co-creators of the world around them, as well as passionate experts in their field.

We consider cooperation with practice to be key for the **further content direction of education in the given field**. We strive to prepare graduates with the greatest possible degree of readiness for real practice, "**educating today for tomorrow's needs**". This cooperation is necessary for the needs of minimizing the impact of Industry 4.0 and 5.0 on employment in the given sector. It is estimated that 45 to 75% of jobs will be affected by the impact of introducing the industry 4.0 and 5.0 philosophy. On the one hand, many positions as we know them today will disappear or be partially transformed, and on the other hand, a large spectrum of job positions will be created for which we are currently unable to prepare a graduate. Cooperation is essential within the entire spectrum of entities operating in the given sector. From the level of sector councils and professional associations to individual production units. This cooperation is mutually beneficial, the school has a clear idea of the requirements for a graduate, it gains access to unique technologies and know-how, and the involvement of practice is also an important motivating factor for students. On the other hand, the manufacturing sector receives a graduate who is ready, and his adaptation is not so financially and time-consuming. The advantages of hybrid forms of education include:

- *Close cooperation between the company, the school, and the student.*
- *Practically targeted curricula for the given fields.*
- *Development of professions linked to market needs.*
- *High probability of obtaining an employment contract with the employer.*
- *Improving the possibility of professional competences and work ethic of school graduates.*
- *Real working, social situations and learning the "corporate culture".*
- *Selection of skilled graduates and their employment for the company's own needs.*
- *Creating educational programs according to the forms and needs of employers.*
- *Strengthening the social status and attractiveness of technical professions - the position of "honest craft".*
- *The participation of employers in raising the professional level of teachers of vocational subjects and Master of Vocational Education.*

As the part of the strategy of involving practice in the teaching process, the founder of the school himself has an important role. He must be convinced of the benefits of the given form of education, as he decides on the amount of allocated funds for the given educational institution. At the same time, his cooperation is beneficial in removing legislative obstacles, which during the creation links school practice stand out.

The success rate of dual education also depends on the legislative framework in the given country.

From our point of view, when involving industrial entities in the teaching process, it is about creating an optimal mix of theoretical and practical teaching. As part of the theoretical teaching, we are talking about guest lectures by experts from practice and consolidation of the theoretical teaching with the help of targeted excursions. As part of practical teaching, it is mainly the completion of long-term internships and involvement in the dual education system.

2. Special guest lectures

The involvement of experts from practice enriches the teaching process and it becomes more up to date, more authentic and thus more interesting for the student. The key is finding a suitable form - to what extent and in what way. It should be noted that in this case it is not a matter of replacing the teacher's work, but of its appropriate addition.

It is appropriate when the involvement of experts in teaching concerns the philosophy of the school and not only the individual activity of the individual/teacher. If the given involvement is to be beneficial and sustainable, it requires the creation of appropriate conditions, whether it is financial coverage or management of the teaching process. It is necessary to choose appropriate forms of participation of experts from practice in the teaching process, which depend on the specific issue, the target group as well as the teaching experience of the visiting lecturer.

In the case of the CNC issue, we selected three main areas where the participation of experts from practice would be appropriate.

a) Wood processing industry

The woodworking industry, like other sectors of our economy, is undergoing a transformation to the industry 4.0 and 5.0 production model. The use of a given production model as well as modern computer-controlled technologies requires a change in approaches in the organization and management of companies. The goal is to present examples of companies that have successfully mastered the given process and bring closer what students expect as their employees in the given companies, what requirements will be placed on them.

b) CNC machines and tools producers

The woodworking industry is one of the most complex in terms of the variety of machinery, technology, and tool equipment. The goal in the given area is to present what the given market in the given area offers, where it is headed, to present new technological and material innovations.

c) CAD/CAM software producers

It should be emphasized here that it is not only about the software itself, but also about the overall software connectivity. For the current graduate, it is important not only to master the work of CAD/CAM software, but to understand that they are part of higher corporate CA systems.

Co-funded by the Erasmus+ Programme of the European Union

An important role in professional lectures is played by the teacher himself, who takes on the role of not only the organizer, but also the moderator of the professional lecture. The teacher knows the dynamics of the collective as well as the internal climate of the class and knows how to properly stimulate it to create a mutually stimulating environment. The teacher should work with the lecturer not only within the framework of the professional lecture itself but should also cooperate in the preparation of the lecturer.

As with other activities, the motivation of students is important, and especially the motivation of students to actively participate in the lecture in the form of asking questions and discussing with the lecturer.

It is necessary to identify a suitable target group, the group should be similar in terms of knowledge and interests. The lectured topic should correspond with the study plan. After completing it, it is necessary to find out the feedback and, where appropriate, to explain what was not understood.

It is necessary to choose a suitable form of lecture (an online form is also possible), but primarily it is advisable to choose a contact form. The scope of the professional lecture is 45 to 90 minutes.

3. Excursions

In the name of the slogan "it is better to see once than to hear a hundred times", field trips to production companies and visits to exhibitions also play an important role in the teaching process.

a) Wood processing industry

Excursions to manufacturing companies are an excellent opportunity to materialize what has been learned/retold. As with other activities in the pedagogical process, proper organization is key. It is necessary to realize that this is an environment with a high risk of injury, which is also noisy. It is necessary to specify the goals that we want to achieve with the given excursion and then discuss them with the company and plan the appropriate course of the excursion.

The goal is to become familiar not only with the technology used in the given company, but also with specific production procedures, organization of the production process, product quality control, organization of workplaces.

In addition to the direct effects of education in the given area, cooperation with companies also brings the development of other competencies of students such as entrepreneurial and communication competencies.

b) Exposition events and machine showrooms

Exhibitions represent an excellent opportunity to get a more comprehensive view of the issue in a relatively short space of time. The question of the real impact of the exhibition on the student depends on the degree of his motivation. As with other activities, here it is necessary to define the goals that the student should achieve with the given exhibition too. We recommend preparing tasks for students to complete during the visit.

Co-funded by the Erasmus+ Programme of the European Union

4. Practical traineeships

Practices, whether it is dual education or various forms of company practices, allow the student to get the most realistic view of the company's functioning. It is the practice that helps the student gain a realistic view of what awaits him in his professional life and the opportunity to clarify his future direction. For this reason, the selection of companies as well as the tutors themselves, who will attend to the students, is key. It is necessary to consider not only the focus of the company, but also its size and company culture. It is suitable if the practice has a rotational nature (alternating departments) or at least it includes a "round" through the company's departments. Communication is important - student, school, and company, which must be three-way and constant.

From an organizational point of view, this is the most demanding form of cooperation between the school and production practice. It is not only the legislative framework of the given cooperation, the need to treat the contractual relations between the school, the industrial entity and the student that is demanding, but especially the preparation of education in the industrial entity itself.

The participation of external entities such as the founder of the school or social organizations that act as a mediator between the school and the industrial entity is appropriate here. It is appropriate when the state organization or the founder within their structures creates space for the employment of "dual education coordinators" specialists who methodically advise schools on the given issue. The ideal case is when a social organization takes the dual system under its patronage and begins to solve the issue comprehensively. As he knows his members, he also knows their possibilities of involvement in dual education. As it brings together experts from the given field, it has the potential to assess the suitability of the given industrial entity's "accreditations" to carry out dual education.

It is necessary to point out that in this case it is not only about educating the students themselves, but it is also necessary to educate the workers - instructors who will take care about the students in the given industrial entity.

Instructors are regular employees of a company or enterprise who must undergo education and training that will ensure their professional readiness for the student education system.

- *Any natural person who meets the given requirements can be an instructor:*
- *regular employee of a company or enterprise,*
- *completed secondary vocational education in the given field of study, in which*
- *practical teaching takes place,*
- *Completed complete secondary vocational education in the given field of study, in which*
- *practical teaching takes place,*
- *completed higher professional education*
- *has been working in his field for at least three years,*
- *completed training for instructors and has a confirmation from the state organization,*
- *which will be provided by the employer.*

It is preferred if they are workers with previous experience in the adaptation of new employees. But when it comes to ordinary production, technical and economic workers or administrative workers without previous experience, their training and methodical guidance by the school is essential.

From the point of view of implementation of the practice, it is expedient when the given practice takes the form of an adaptation process of a new employee and the company, and the training employee treat the student as an employee in the adaptation process. It is not appropriate when the student becomes only an inactive observer without personal interest in the production process.

The form and course of the practice depends on the size and internal structure of the subject in which the practice is carried out. From the point of view of the acquired knowledge of the skill, it is suitable when it is a medium or large subject. It is advisable to start the practice itself with a general "round", where the student goes through the individual departments of the company, gets to know the internal structure and functioning of the company, and after completing the "round" completes intensive practice in the required departments. From the point of view of the scope of the given methodology, two departments of job positions are interesting:

a) *production department for the position CNC operator traineeship*

the training will be focused on preparing the CNC machine for work, operating the CNC machine during program implementation, solving common operating faults, checking the quality of the workpiece and tool management

b) *production preparation department: CNC programming traineeship*

the training will focus on the creation of a program for CNC machines, the choice of machining strategies and technological machining conditions

It is important to clearly define in the contractual documents:

- *school educational program for this type of education,*
- *curriculum and thematic plans, content, and performance standard professional subjects,*
- *cooperation of vocational education masters and education instructors, mutual consultations,*
- *organization of practical teaching,*
- *draft schedule for students, alternation of practical and theoretical teaching,*
- *conditions for assessment and classification of students,*
- *maintaining relevant documentation,*
- *method of completing studies, dates, and forms of the final exam,*
- *method of financial evaluation of students,*
- *familiarization of all process participants with the company's internal rules or company and place of practical training, also with OSH principles.*

The implementation of practice itself can be either in the form of a long-term internship or in the form of the implementation of dual education.

A characteristic feature of dual education is the connection of general, theoretical education at school and practical training at the workplace of the employer, with whom the

Co-funded by the Erasmus+ Programme of the European Union

student concludes a dual education contract. In practice, this means that the student learns how to use the theoretical knowledge from school in practice at the employer's workplace, since he already works in real conditions at the workplace during the education. This gives the student the opportunity to create a partnership, working relationship with his employer, with whom he can continue to work even after the end of the dual education.

c) School staff training and consultations

The need for production experience is not defined in the qualification requirements for a teacher of a professional subject. It often happens that it is a university graduate without any experience in the production sphere. Although the given teacher is an expert in the given field, he does not understand the environment for which he is preparing the student. For this reason, it is appropriate that every new teacher, as part of their adaptation, also completes a "round" in a manufacturing company, where they would try out the professions for which they are preparing graduates. The given practice will help future teachers to better understand inter-subject connections and what is essential for the graduate, and at the same time it will also provide him with real examples for the application of the taught subject matter.

5. Collaboration projects

In addition to technical knowledge, real practice requires many more competencies such as the ability to work in a team, presentation skills, etc. Student competitions, conferences and seminars are an excellent opportunity for deepening.

a) Student competition calls

These are competitions where students solve technical and creative challenges in small groups. Students learn teamwork against the background of solving challenges. Students could compare their knowledge and skills with students from other schools/teams.

b) Conferences, seminars, and workshops

They are an ideal opportunity to learn more about the given issue and to build your personal network with people with the same or similar interests. Students are not just passive receivers of information but could have an open discussion on the topics addressed, thus developing their critical thinking and communication skills. They acquire an important role in the further education of teachers, how to follow the latest trends in the field.

c) Final theses assigned by practice

A suitable form is also the solution of final/graduate theses assigned by production practice. The given work can be mutually beneficial, the student participates in a real problem, which motivates him to perform more responsibly/professionally, and the company often gets an innovative, fresh solution. In addition to practical experience in solving a real problem, the student expands his communication skills.

Co-funded by the Erasmus+ Programme of the European Union

Pillar V: Interinstitutional cooperation

1. Staff exchange

a) Excursion mobilities

Within the program, mobilizations are carried out, through which employees perform one-day or multi-day mobilizations, where they see and test good practices in the use of various technologies in smaller and larger companies. The focus of the mobilizations are companies and organizations that, with their innovative approach, philosophy and positive work environment, encourage and practice the use of the latest technology. Mobilizations can also be carried out in related educational institutions with which they have regulated legal and formal relations and which are ready to share their experience and knowledge.

The possibility of these mobilizations would also be where employees can be sent for intensive training to a partner institution, mainly in terms of upgrading their knowledge, where their technology is tested and used and developed (under mentoring), and each participant in this way completes their knowledge and expands their horizons.

Another option is the one where intensive training is organized and carried out for both employees and guest participants of partner institutions, in the company (real sector) which offers and facilitates the education of personnel coming from education, where it presents and offers them the opportunity to train and use CNC technologies.

The aim of the mobilizations is intensive awareness raising and learning about accessible information, which the respective organizations use and which like to share what they have obtained for them. Examples of good practices can be from all branches, not only the wood industry, but almost all professions, because only in this way can a newer, more modern idea take hold, in which the technology could be invested or adapted for use in the wood industry.

b) External lectures

Employees give lectures in their field at institutions that support it or with institutions that have a mutual cooperation agreement. Lectures are focused on the area covered by the lecturer. These can be one-hour lectures, where general knowledge of the field is explained and shown, or they can be continuous lectures that can last from one week to one semester. However, if the subject is so extensive, it can be carried out for an entire academic year.

A weekly or 14-day lecture is held in a condensed term, where the lecturer lectures and guides a certain smaller (selected) number of students. The final product is a smaller product, a project assignment based on the use of hosted technology or technology that they can also use in the economy.

The semester or whole study year lecture is carried out according to the schedule determined by the host organization. The weekly sessions escalate into a more complex study model where in addition to the final product, there are also weekly presentations by students under the mentorship of a visiting professor, at the end they present the progress of the project and a practical demonstration and product.

The goal of this is to enable diversity in the implementation of programs, to offer students several different approaches to the use and implementation of modern technology in educational systems, and consequently to prepare them for real employment, as well as to enable employees to try new challenges. Globally, to enable everyone to communicate in a foreign language and bring the philosophy and topics of the partner institution closer to students as future users who will be responsible for development.

c) International subject councils

Organizations that have a mutual agreement on the implementation of the study program meet regularly once a year (before the beginning or after the end of the academic year), where they debate the expected results, design joint practices, and decide on details regarding the implementation of the content. Presented are new models, new technologies that are accessible and that can be tested and can be included in the study process. At this council, mutual projects can also be discussed, which can contribute to better information and education of future graduates and these projects can also be used to rank higher in the world rankings, especially at world fairs (Koln fair, Expo...)

Mutual management systems can be established on the basis of which criteria, levers and goals are determined to encourage the deployment and implementation of the set program, because fresh eyes look at the problems of others from a completely different angle, thus new methods and approaches can be developed and above all, new solutionscan be specified to a specific problem. It is also possible to organize partnership funds with which one institution finances another in terms of improving technological equipment and as a result, mutual cooperative cooperation and exchange of personnel in exchange for closer cooperation and the implementation of more complex projects with which they are candidates at the national level.

2. Exchange of students

a) Bilateral partnerships

Two or more partner institutions that have signed an agreement for mutual cooperation exchange 2-5 students (from each institution) who are enabled to study at the other institution. The choice of free content in the study curriculum increases in addition to the fact that students can choose from various subjects that interest them and that they take as part of the study obligation.

b) International graduation teamwork

One of the options for completing the studies is the so-called international graduation team work, where the student completes the graduation at one of the partner institutions. Under the mentorship of the partner institution, the student completes the final assignment in its entirety. The basis for the assignment can be a few weeks of practical training and learning about the problem, through which the topic and the problem of the assignment are then conceived. The scope of the topic is defined by the head of the institution, who also specifies the criteria and expected results. A surplus of tasks, a useful and realistic solution that the company needs and, last but not least, the future employment of the student in this position.

Another form of completion is the cooperative cooperation of a maximum of two students with two co-mentors from both institutions, who jointly define the problem and jointly attempt to solve it. In conclusion, they develop and present concrete solutions to the chosen problem, either in a theoretical sense or in a concrete implementation in a practical sense. Emphasis is placed on the use of the latest technology that is available and that the specific problem needs.

c) Double degree programs

Co-funded by the Erasmus+ Programme of the European Union

The educational programs, which are unified and approved by the Ministry and which are equally evaluated for credit according to the standard European scoring system (European Credit Transfer System - ECTS), students can obtain an authentic education both at one and at the other institution. Both institutions implement programs in such a way that students can complete a certain part of their study obligations at one or another institution (100%-0%, 40%-60%, 50%-50%, 60%-40%).

When choosing the category 100%-0%, the program is carried out exclusively at one institution, before graduation the graduate must take a differential exam at the partner institution, which covers the missing content before his education at both institutions is recognized.

The choices (40-60, 50-50 and 60-40) represent an ideal combination of a study program where a sufficient amount of knowledge and experience is accumulated during the education, supported by practical experiences, with which the student reaches the conclusion and which allows him a wide range of graduation and employment abroad.

d) Study recognition partnerships

Each institution recognizes the degree of the study program agreed with the partner institution, with which the student or the graduate acquires the education of both institutions. Both institutions must be programmatically unified at the level of theoretical treatment of professional material and terms, as well as at the practical level, where the student gains the necessary experience and knowledge. If there is a certain deficiency in some area, it can be upgraded without any problem at a partner institution, which has a wider range of knowledge.

3. Special twinning events

a) International student competition

Certain student competitions can be held, with different contents, where in the foreground is more or less socializing, exchange of experiences-views on a certain problem. In terms of content, a joint project is carried out that tackles a specific problem (it can even be a competition at the national or local level), where the best solution is finally chosen, with use of CNC technology, which is available. In the second part, the practical creation and implementation of the project in reality is carried out, where students actively participate in the preparation and creation of a concrete task.

There can also be a joint or group exhibition of projects created during the academic year, which can then travel to different institutions or countries.

b) International conferences

Participation of students in international conferences, as listeners or as active members who can participate in these events, where they can prepare a shorter or more extensive presentation on a topic that is current. Above all, it is about concrete examples of the use of technologies in projects, what kind of projects were created with an innovative individual or group approach. It is presented where and how the project has already been presented (fair, exhibition, regional presentation,...).

Conferences can be designed as one-day events, where there are several different presentations and lectures with a conclusion at the end (a tour of the latest technology), or several day-long events where, in addition to the presentations, various short-intensive training workshops are organized, up to excursions in companies.

The income that students can obtain from this is participation in such events, in addition to being recognized for a certain part of their study obligations,

c) Collaboration projects

Institutions cooperate with each other with joint projects on various topics. The projects complement the study obligations, but they can also be thought of as an addition, which interested students take as an elective. The range of tasks ranges from theoretical to practical challenges that solve real problems. The projects are designed in such a way that first a study of the situation is carried out, a critical definition and then the creation of solutions in groups. In the end, the best solution is chosen, which is practically implemented.

Co-funded by the
Erasmus+ Programme
of the European Union

References

Katz, Deirdre A., Mark T. Greenberg, Patricia A. Jennings, a Laura Cousino Klein. 2016. „Associations between the Awakening Responses of Salivary α-Amylase and Cortisol with Self-Report Indicators of Health and Wellbeing among Educators". *Teaching and Teacher Education* 54 (únor): 98–106. https://doi.org/10.1016/j.tate.2015.11.012.

Kinnunen, Ulla, Terttu Parkatti, a Anne Rasku. 1994. „Occupational Well-being among Aging Teachers in Finland". *Scandinavian Journal of Educational Research* 38 (3–4): 315–32. https://doi.org/10.1080/0031383940380312.

Maslach, Christina, Wilmar B. Schaufeli, a Michael P. Leiter. 2001. „Job Burnout". *Annual Review of Psychology* 52 (1): 397–422. https://doi.org/10.1146/annurev.psych.52.1.397.

Skaalvik, Einar M., a Sidsel Skaalvik. 2011. „Teacher Job Satisfaction and Motivation to Leave the Teaching Profession: Relations with School Context, Feeling of Belonging, and Emotional Exhaustion". *Teaching and Teacher Education* 27 (6): 1029–38. https://doi.org/10.1016/j.tate.2011.04.001.

Truch, Stephen. 1980. „Teacher Burnout and What to Do About It".