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MakeMyFuture
Modules

VET Maker Based modules for industry 4.0

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MakeMyFuture - Improving Digital Competences for Advanced Manufacturing Industries through Maker Education

R2 - MakeMyFuture Modules

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Introduction

The MakeMyFuture Modules is the second result of MakeMyFuture project, an Erasmus+ KA2 Cooperation Partnership project in Vocational Education and Training, co-funded by the European Commission. The project aims at supporting VET teachers in implementing maker-based activities for providing VET students with advanced digital competences, in line with the changes of Industry 4.0.

This document provides a maker-based training path for VET students aiming to support the achievement of advanced digital competences in line with the Profiles previously identified by the R1 MakeMyFuture Competence Framework.

The training path has been designed, and structured into modules in order to gradually align the learning outcomes of VET students with the advanced digital competences required by Industry 4.0.

The modules have a clear framework describing timing, type of activity, tools and materials needed, steps to be implemented, assessment methodology and skills, knowledge and competences acquired. It combines a knowledge/theoretical component with original hands-on activities based on the main digital technologies used by Fablabs and Industry 4.0 in partner countries (Italy, Spain, Germany, Malta, and Poland).

Industry 4.0 technologies are considered by the European Union as horizontal technologies “enabling” multiple sectors that are expected to be decisive in tomorrow’s economy (EC, 2019 Curriculum Guidelines for Key Enabling Technologies and Advanced Manufacturing Technologies). Despite the great potential of these technologies in supporting youth employment, there is a lack of appropriate and multidisciplinary curricula providing related digital skills. This is identified as a key barrier also to the development of innovation and digital transformation (EC 2020 Youth Employment Support: a bridge to jobs for the next generation).





In this document, in addition to the detailed description of the profiles, you can find also a description of the methodology implemented by the MakeMyFuture partnership. This will enable other organisations and countries to do the same process and adapt the Modules to their contexts and interests.

Methodology

This document has been produced by the MakeMyFuture partnership based on a process involving different stakeholders.

Phase 1

During the first phase, the partnership mapped the profiles highlighted in the Competence Framework with the technologies and activities used by the Fablabs, in order to select the most relevant profiles that could be implemented with the Making approach in the different partner countries. The partners selected the following 4 profiles:

-  Profile 1. Additive Manufacturing technician
-  Profile 2. CNC operations technician
-  Profile 3. CAD/CAM Technician
-  Profile 7. Robot machines technician for Industry 4.0

Based on this, specific learning outcomes were associated for each module.

During the second phase, the leading partner (FabLab München e.V.), in collaboration with the partnership and especially with the schools, defined the framework, contents and layout for the modules taking into account the VET curricula.

Phase 2

Phase 3

Finally, each partner contributed to the development of the modules according to the specific expertise.

Modules

Profile 1. Additive Manufacturing technician

Competences acquired

C1. Ensures a smooth and reliable basic operation of 3D printing machines, setting up, maintaining and repairing additive manufacturing and 3-D printing equipment.

Module 1. Introduction to Additive Manufacturing

Duration: 10 hours EQF:4 ECVET: 0,4 C

Activity 1 - Presentation

Step 1: Present students with an overview of what additive manufacturing is

Activity 2 - Individual research (it can be done also as homework)

Step 1: Ask students to autonomously research the different additive manufacturing systems and take note of their main features

Step 2: Ask students to provide a chart for every system found (the chart should be provided in advance and include: the name of the system, how the system works, how it is used by industry 4.0, what are the pros and cons at industrial level)

Activity 3 - Group work

Step 1: Divide the students in groups

Step 2: Ask groups to share the information found at individual level and to prioritise the most used additive manufacturing systems.

Step 3: Ask groups to create a presentation for the different additive manufacturing systems

Activity 4 - Open discussion

Step 1: Ask students to discuss together as a whole group in order to create a list of additive manufacturing systems actually used by industry 4.0, describing their main features. The teacher guides the discussion and provides extra information if needed.

Tools and materials needed: Internet connection, PC.

Learning Outcomes acquired:

- K1 To describe what additive manufacturing is and how the different systems work
- K2 To recognise the advantages, opportunities and benefits of the different systems of Additive Manufacturing

Assessment methodology: the achievement of the learning outcomes will be evaluated assessing the information included in the presentations provided by the student groups.

Module 2. Develop Prototype and Product: 3D printing software preparation / slicing / G-Code generation

Duration: 13 hours EQF:4 ECVET: 0,5 C

Activity 1 - Presentation of different 3D printing systems and slicing tools (2 hours)

Presentation of the teacher:

Step 1: Students get an overview of 3D printing systems like FDM printer, Resin Printer and Lasersinter machines and the most popular printers and its use in industry 4.0

Step 2: Students get an overview of different slicing tools to produce G-Code and pictures for the printers to finally produce a 3D object out of a 3D design

Step 3: Students summarise the most popular 3D printers and slicers and its use for industry 4.0

Activity 2 - Slicing and G-Code Generation for FDM Printer (6 hours)

Step 1: Teacher presents two popular slicers for FDM printing - Cura and Prusa Slicer (30 minutes)

Step 2: Teacher demonstrates the slicing with Cura with different settings (45 minutes)

Step 3: Teacher demonstrates the slicing with Prusa Slicer with different settings (45 minutes)

Step 4: Pupils get a stl. file and try to prepare a printing file choosing either Cura or Prusa Slicer (3 hour)

Step 5: Teacher helps the students to get the file preparation right and sums up again what has to be taken into account before starting the print (1 hour)

Activity 3 - File preparation for Resin Printer (4 hours)

Step 1: Teacher presents how to prepare a file for resin printing (30 minutes)

Step 2: Pupils prepare the files for resin print (2,5 hours)

Step 3: Teacher helps the students to get the file preparation right and sums up again what has to be taken into account before starting the print (1 hour)

Activity 4 - Open discussion

Step 1: Pupils present their results and discuss the problems, difficulties or smooth running of their file preparation (1 hour)

Tools and materials needed: slicing software, PC, internet

Learning Outcomes acquired:

- S1 To prepare and manage the files for printing
- K3 To describe the sequence of process step
- K4 To describe how to prepare and manage the files for printing

Assessment methodology: The achievement of the learning outcomes will be assessed through the evaluation of the piece projects realised by the students.

Module 3. Processing Techniques with different types of 3D printing machines

Duration: 35 hours EQF:4 ECVET: 1,3 C

Activity 1 - Overview (2 hours)

Step 1: Present the students with an overview of the quality standards and indicators of the additive manufacturing products; maintenance indicators and diagnostic techniques and the more appropriate printing material for the specific 3D printer in relation to the specific field of application.

Activity 2 - Preparation and calibration of FDM Printer (6 hours)

Step 1: The teacher presents to the students how to prepare and set up the specific additive manufacturing system, which materials have to be used, do's and don't's and how to do the calibration and change of filament, etc (1 hour)

Step 2: Guide the students in setting up the printer. The teacher will guide the process by following the steps below, i.e. setting up bed leveling and axis travel, setting up coordinate origin positioning, extruder control, and loading the print material. (4 hours)

Step 3: Ask students to share any difficulties encountered during the activity. The teacher will guide the discussion and will provide useful tips, if needed. (1 hour)

Activity 3 - Start an FDM print (12 hours)

Step 1: At least one Ultimaker and one Prusa Printer have to be organized

Step 2: Each student should have the possibility to start a print by himself, transfer files to the printer (SD Card, USB Stick, WLAN), change the material of the printer, do the calibration, check the smooth running of the print and remove his print on both printers - so everyone can do the whole process of starting and removing a print. (11 hours)

Step 3: Presentation and discussion on the results - difficulties, problems, what went well, what did not work (1 hour)

Activity 4 - Demonstration of the preparation of a resin printer (1,5 hours)

Step 1: Teacher presents the preparation of a resin printer and explains the materials used and the do's and don't's (1 hour)

Step 2: Students sum up and describe what they learnt (30 minutes)

Activity 5 - Start a print with Resin Printer (12 hours)

Step 1: At least one Resin Printer should be organized

Step 2: Each student should have the possibility to start a print by himself and clean the printed object and the printer after the print (11 hours)

Step 3: Presentation and discussion on the results - difficulties, problems, what went well, what did not work (1 hour)

Activity 6 - Open discussion

Students share their results and their learning with each other (1 hour)

Tools and materials needed: Prusa Printer, Ultimaker Printer, Resin Printer, Resin, Filament FDM, Sidecutter.

Learning Outcomes acquired:

- S2 To properly prepare and set up at least 1 additive manufacturing system
- S3 To properly operate basic tasks using at least 1 additive manufacturing system
- S4 To check and ensure the quality of the products
- K5 To describe the quality standards and indicators of the additive manufacturing products
- K6 To describe maintenance indicators and diagnostic techniques
- K7 To understand the more appropriate printing material for the specific 3d printer, with respect to the object to be printed.

Assessment methodology: The achievement of the learning results will be evaluated, assessing the quality of the pieces made by the students.

Profile 2. CNC operations technician

Competences acquired

C2. Operates basic tasks using a Computer numerically controlled (CNC) machine.

Module 1. Introduction to CNC

Duration: 25 hours EQF:4 ECVET: 0,9 C

Activity 1 - Lesson - machine tools

Step 1: Present students with a general overview of what a CNC machine is.

Step 2: Present students with a brief history of machine tools starting from the early wood lathes until the modern fully automated machining centres.

Step 3: Summarise what was discussed.

Activity 2 - Open discussion - CNC machine tools advantages and disadvantages

Step 1: Present students with a brief summary of activity 1.

Step 2: Guide an open discussion comparing and contrasting a modern CNC machine vis a vis a manual machine tool. CNC machine advantages and disadvantages should emerge from this discussion where these points are listed on the whiteboard.

Activity 3 - Lesson - How a CNC works

Step 1: Present students with a brief summary of activity 2.

Step 2: Present students how a CNC machine works. (A G code program is fed through the input device, it is read by the MCU, the CLU converts the instructions into electric signals, these are sent to the axes drives which move the machine head or table and the workpiece is cut to the desired shape.)

Activity 4 - Demonstration

Step 1: Present students with a brief summary of activity 3.

Step 2: Show students a demonstration of a working CNC machine is shown to the students. (No set-up is required at this stage. The demo should show the capabilities of the machine)

Activity 5 - Lesson - Applications of CNC

Step 1: Present students with the applications of CNC in manufacturing engineering. The teacher will introduce different processes requiring CNC machine tools including; lathes, milling machines, laser cutters, laser welders, laser hardening, water jet cutters, plasma cutters, EDM, wire EDM and additive manufacturing machines. For each CNC machine, typical products are shown.

Activity 6 - Industrial visit

Step 1: An industrial visit is organised to show some of the machines described in Activity 3 in action.

Activity 7 - Quiz - Select the best CNC machine to manufacture a given product.

Step 1: Have students take an educational quiz (can also be online) in which they are asked to select the best CNC machine tool to produce a given product.

Tools and materials needed: A CNC vertical milling machine with different cutters, a work holding device (eg. vice) and raw material (eg. aluminum flat bar 20mm thick), a classroom equipped with a computer, audio-visual system (big screen, or projector) and whiteboard.

Learning Outcomes acquired:

- K1 To describe what a CNC machine is and how it works.

Assessment methodology: This module is best assessed by a class examination. Students are to be assessed on their knowledge of each activity of the module.

Module 2. The CNC milling machine

Duration: 75 hours **EQF:**4 **ECVET:** 3 C

Activity 1 - Lecture - CNC milling overview

Step 1: Present students with a general overview of the CNC milling machine. Videos could be shown of different machines being used in different industries (electronics, automotive, aviation, marine, etc.)

Step 2: Narrate and discuss any experiences of working with a CNC milling machine.

Activity 2 - Workshop session - CNC milling machine parts

Step 1: Present students with a brief summary of activity 1.

Step 2: Illustrate the different machine parts of a CNC milling machine. Including; The machine table, ball screws, axes drives, spindle, spindle drive, rails, ATC, tool magazine, MCU, HMI, coolant, oil, electronics cabinet...

Step 3: Ask students to individually sketch and label a CNC vertical milling machine. .

Activity 3 - Workshop session - Cutters

Step 1: Present students with a brief summary of activity 2.

Step 2: Show the students the different milling machine cutters including; a face mill, an end mill, a slot drill, a ball nose cutter, a twist drill, a spot drill and a chamfering cutter.

Show the students the cutter geometry. (Students do not need to learn the mechanics behind the cutting process but only to know that the cutter geometry is different for different materials.)

Step 3: Show the students the different cutter materials, solid cutters and cutters with replaceable inserts. Different cutter coatings are also shown and the advantages of different coatings are discussed.

Typical cutter prices are also of interest to students.

Activity 4 - Lecture - Machining parameters

Step 1: Present students with a brief summary of activity 3.

Step 2: Present students with the cutting parameters in milling. Cutting parameters include; RPM, feed, type of cutter, cutter material, depth of cut, the width of cut, feed per tooth and cutting speed. Up-milling and down-milling are also discussed and a list of advantages and disadvantages is compiled.

Step 3: Students are presented with 2 ways to decide the cutting parameters - either by using a specialised app or by using machining charts and performing a calculation. Both ways are described and discussed in detail.

Step 4: Divide the students into 2 groups, giving them an example where stock material needs to be machined. Group 1 will calculate the machining parameters and Group 2 will use the app. The results will then be compared with each other. Another example is repeated and the student groups now swap methods.

Activity 5 - Workshop session - machine introduction (2, 3 students per CNC machine, 100% supervision)

Step 1: Show the students how to switch on the machine, health and safety labels - what they mean and why are they important.

Step 2: Show the students the different machine modes, software menus and how to move the machine axes using the jog and hand wheels.

Step 3: Show the students how to set up the tool magazine and label the tools in the machine's tool register.

Step 4: Show the students how to align the work-holding device to the work table and secure it in place. A dial indicator is needed for this. Then show them how to align and secure stock material ready for machining.

Step 5: Ask students to operate the CNC machine in MDI mode. First by facing the stock material and then other operations such as peripheral milling and cavity milling. It is good that they try both up milling and down milling and the surface finish of both cuts is compared.

Step 6: Show the students how to remove the workpiece and how to clean the machine from the generated swarf. Students are encouraged to collect samples of swarf generated in different operations and compared them together. The colour, thickness, and length of the swarf are indicative of the health of the machining process. An appreciation of this is important.

Tools and materials needed: A CNC vertical milling machine with different cutters, a work holding device (eg. vice) and raw material (eg. aluminum flat bar 20mm thick), a classroom equipped with a computer, audio-visual system (big screen, or projector) and whiteboard.

Learning Outcomes acquired:

- K2 To describe the work cycle and steps to operate a CNC machine
- S2 To set up a CNC machine properly

Assessment methodology: Learners are assessed through a short individual assessment after the completion of all activities. The students are to be supervised when operating the machine and a checklist of what was learned or achieved by each student individually could be filled by the supervisor. An interview assessing the student's knowledge of the milling machine parts and their function could also be carried out.

Module 3. The CNC process

Duration: 25 hours EQF:4 ECVET: 0,9 C

Activity 1 - Lesson - Tolerances

Step 1: Present students the manufacturing processes and natural variation in manufacturing.

Step 2: Present students what are manufacturing tolerances and their importance in engineering.

Step 3: Present students the standards when writing tolerances.

Step 4: Present students geometric dimensioning and tolerancing. Symbols used and their meaning.

Activity 2 - Classwork - Engineering drawings

Step 1: Present students with a brief summary of activity 1.

Step 2: Show the students a presentation on orthographic drawings.

Step 3: Assign students an exercise in which they receive orthographic projections of different parts and draw an isometric view of the parts.

Activity 3 - Lesson - The CNC process

Step 1: Present students with a brief summary of activity 2.

Step 2: Discuss the CNC process with the whole class as the process starts from the engineering drawings and transforms the stock material into something of value. In general, the CNC process is; Drawings → stock material selection → machining sequence → machine tool choice → work holding device selection → cutting tool selection → plan tool paths → calculate process parameters → operational planning → G Code generation → simulation → part machining → part inspection.

Activity 4 - Class exercise - operational plans

Step 1: Present students with a brief summary of activity 3

Step 2: Divide the students in groups of 2. Each group is given the engineering drawings of a part and they are given 30 minutes to write a standard operational plan (handouts need to be prepared beforehand). Each group presents his operational plan to the rest of the cohort. Discussions are encouraged. This activity is to be repeated until students can master the planning of simple engineering components.

Activity 5 - Workshop session - the calliper and micrometre screw gauge

Step 1: Present students with a brief summary of activity 4.

Step 2: Give to the students engineering parts, a digital calliper and a digital micrometre and they are shown how to use them.

Step 3: Show the students a presentation on how to take care of a precision instrument.

Step 4: Give the students an engineering part and its drawing. The student measures it and writes a measurement report. (The tolerances on the part drawing are to be written in such a way that both instruments need to be used).

Tools and materials needed: a classroom equipped with a computer, audio-visual system (big screen, or projector) and whiteboard; a workshop equipped with a surface plate, electronic callipers and micrometres; a number of engineering components together with their engineering drawings.

Learning Outcomes acquired:

- K3 To describe the quality standards and indicators for CNC operations and products.
- S1 To interpret the technical-mechanical drawing in CAD.
- S4 To check and ensure the quality of the product.

Assessment methodology: Students are assessed individually by 2 assignments. The first assignment (60%) is a home assignment where the student is presented with an engineering drawing and he applies his knowledge of the CNC process to write an operational plan to machine the part from scratch. The second assignment (40%) is done in the workshop where the learner is given a physical part and its engineering drawing and he needs to measure all the dimensions, write a measurement report and finally accept or reject the part.

Module 4. Basic G - Code programming

Duration: 50 hours EQF:4 ECVET: 1,8 C

Activity 1 - Lesson - G00, G01, M03, M04, G90, G91

Step 1: Present students the machine axes and the need for a standard cartesian coordinate system. Introduce students to G90 and G91.

Step 2: Present students the difference between G and M codes. Common G and M codes including G00, G01, M03 and M04.

Examples:

1. A facing operation.
2. machining a workpiece with drilling operations only.
3. machining a workpiece with straight slots.

Activity 2 - Lesson - G20, G21, G70, G71, M05, M06

Step 1: Present students with a brief summary of activity 1

Step 2: Present students more G codes - G20, G21, G70, G71

Step 3: Present students modal and non-modal letter addresses

Step 4: Present students M05 and M06, Program structure - Setup phase, material cutting phase, shut down phase. Show them an example of a short G-Code program and split into its different phases.

Activity 3 - Workshop session - Datum setting and auto mode machining. (2, 3 students per CNC machine, 100% supervision)

Step 1: Show the students how to probe the workpiece with an edge finder and to set the workpiece datum on the CNC machine.

Step 2: Ask students to write a short G - code program for a given workpiece (parameters are all given) and machine the part in automatic mode.

Step 3: Ask students to measure the part and accept or reject it. In case the part is not acceptable, students are to think and reflect to find out any possible reasons why.

Activity 4 - Lesson - Circular interpolation

Step 1: Present students with a brief summary of all G codes covered.

Step 2: Present students the G02 and G03

Step 3: Assign students an exercise in which they have to write the G-Code program of a part with circular features.

Activity 5 - Lesson - Cutter compensation

Step 1: Present students with a brief summary of all G codes covered.

Step 2: Present students the Cutter diameter compensation and Cutter length compensation

Step 3: Present students the G04

Step 4: Show students a programming example

Activity 6 - Lesson - Canned cycles

Step 1: Present students with a brief summary of all G codes covered.

Step 2: Present students the Canned cycles - G80, G81, G83

Step 3: Show students a programming example using canned cycles.

Activity 7 - Lesson - Subroutines

Step 1: Present students with a brief summary of all G codes covered.

Step 2: Present students what are subroutines and how to use them.

Step 3: Show students a programming example using subroutines.

Tools and materials needed: a classroom equipped with a computer, audio-visual system (big screen, or projector) and whiteboard; a workshop equipped with a surface plate, electronic callipers and micrometres; a number of engineering components together with their engineering drawings.

Learning Outcomes acquired:

- S3 To properly operate basic tasks on a CNC machine.

Assessment methodology: An individual assessment is to be carried out in a workshop where the learner is given an operational plan, a tools list and a set-up sheet to manufacture the part autonomously and ascertain its quality.

Profile 3. CAD/CAM Technician

Competences acquired

C3. Creates basic 2D and 3D Models for CAD/CAM production systems

Module 1. Introduction to CAD/CAM and its use

Duration: 8,5 hours EQF:4 ECVET: 0,3 C

Activity 1 - Face-to-face presentation (2h)

Step 1: Present students with an overview of what CAD/CAM is and its use for work

Step 2: Give students a brief description of the difference between CAD and CAM.

Step 3: Summarise what was discussed

Activity 2 - Group work (4h)

Step 1: Divide the students into groups of 2-3 to work out the different 2D technologies, including data types:

- Students are asked to elaborate on software types from less complex and easy to use-to hard-to-learn and very complex
- Students are asked to do research and write down their results, finding good practice examples on the internet
- Students are asked to find jobs where 2D technologies are used

Step 2: Divide the students into groups of 2-3 to work out the different 3D technologies, including data types:

- Students are asked to elaborate on software types from less complex and easy to use-to hard-to-learn and very complex
- Students are asked to do research and write down their results, find good practice examples on the internet
- Students are asked to find jobs where 3D technologies are used

Step 3: Let each group of students show the results (what software they found, its use and the kind of jobs where it is relevant to know about them) and guide the discussion.

In the end, all groups vote for the best software to use for the purpose of learning CAD/CAM

Activity 3 - open discussion (2h)

Step 1: Guide the discussion on the different software types. Students are asked to compare the software programs elaborated for 2D and 3D and their use guided by the teacher through a template.

Step 2: Lead the discussion on the importance of CAD/CAM for the labour market. The teacher can present a PowerPoint or video on the topic. The students are then asked to discuss the relevance of work and the different work situations in which CAD/CAM is important, also drawing on the material shown by the teacher.

Activity 4 - class examination (30 min)

Step 1: Have students take a short test about what they learned and elaborated.

Tools and materials needed: a classroom equipped with a computer, Internet connection, 2D and 3D programs, beamer and whiteboard.

Learning Outcomes acquired:

- K1 To recognize and understand different files and data types and their use
- K2 To present the different techniques and tools for creating a basic 3D Model for CAD/CAM systems

Assessment methodology: This module is assessed by a class examination. Students are to be assessed on their knowledge of each activity of the module.

Module 2. CAD Software handling - 2D/3D modelling with CAD

Duration: 50 hours EQF:4 ECVET: 1,8 C

Activity 1 - Lesson - History of Engineering design, from pencil and paper to CAD to simulations and generative design

Step 1: Present students with an overview of what is 2D and 3D design. Design vs. drafting (drafting is drawing only, design involves calculations, trials and testing). Cloud-based CAD and its benefits.

Step 2: Present students with how to install a particular CAD software (such as Fusion 360) at home. (Students are encouraged to install such software at home).

Step 3: Show students how to learn from a tutorial on the internet. (Eg. search on youtube how to install Fusion 360).

Activity 2 - Practical session using 2D sketching tools to create a 3D model.

Step 1: The instructor opens a blank sheet and introduces the students to the basic 2D sketching tools (drawing a line, rectangle, circle, etc.) The sketch is then extruded to create a 3D body.

Step 2: The students then are given enough time to repeat the sequence of operations and draw the same body on their own.

Step 3: The different viewing options are shown to students. (Eg. Pan, zoom, orbit, visual style, snap, grid etc.)

Activity 3 - Practical session using 2D sketching tools to create a 3D model

Activity 2 is repeated with more complex 2D sketching tools (arc, polygon, spline, slot, mirror, pattern, etc.).

More complex 3D tools are then introduced in the same manner. (Eg. revolve, sweep, loft, hole)

When introducing students to these drawing tools it is important to present real-life products where these tools are needed to draw the model. For example, to draw a cup, the revolve tool is used. To draw a mug, the revolve tool and the sweep tools are used.

Activity 4

Activity 3 is repeated drawing parts requiring other tools eg. fillet, chamfer, shell, draft, scale, join etc. and also construction entities eg. points, axes and planes.

Tools and materials needed: a PC with CAD software for each student, a classroom equipped with a computer, an audio-visual system (big screen, or projector) and a whiteboard.

Learning Outcomes acquired:

- S1 To properly use 3D Modelling software
- K3 To describe the main steps for creating a basic 2D and 3D Model for CAD/CAM systems

Assessment methodology: an individual assessment is given where students need to draw a number of 3D models (with increasing complexity) from a given part drawing (or isometric view) including dimensions.

Module 3. Manufacturing using CAM programs

Duration: 50 hours EQF:4 ECVET: 1,8 C

Activity 1 - Lesson - Activity 1 - Overview - frontal lesson

Step 1: Present students with an overview of the industrial 2D and 3D Modelling software available.

Step 2: Show students the main steps to be followed for creating a basic 2D or 3D Model for CAM production systems (Sketching, extrude, revolve, sweep, etc)

Activity 2 - How to read engineering drawings - frontal lesson

Step 1: Present the students the parameters to take into consideration when reading an engineering drawing

Step 2: Present the students real engineering drawings to be discussed with the class.

Activity 3 - Guided 3D Model - Simulation

Step 1: Guide students in a step by step process to create a basic 3D model

Activity 4 - Individual work

Step 1: Provide each student with a basic engineering drawing.

Step 2: Ask them to create a 3D Model starting from the drawing. The teacher will provide a checklist with the main steps to be followed.

Step 3: Ask students to present the work done.

Tools and materials needed: a computer lab with a big screen displaying the teacher's monitor and a PC for each student.

Learning Outcomes acquired:

- K3 To describe the main steps for creating a basic 2D and 3D Model for CAD/CAM systems

Assessment methodology: the achievement of the learning outcomes will be evaluated by assessing an individual assignment where the student is presented with an engineering drawing and he/she is to draw the 3D model of the part. It is suggested to have about 3 or 4 drawings with increasing complexity.

Module 4. CAD/CAM Workflow from 3D model to CNC Milling

Duration: 18 hours EQF:4 ECVET: 0,7 C

Activity 1 - Lesson - machining strategies (2 hours)

Step 1: Present students with a general overview of machining strategies for 3 axis CNC milling machines.

Step 2: Summarize what was discussed.

Activity 2 - Practical activity - CAM preparation of a 2.5 milling operation (8 hours)

Step 1: Present students with an overview of the practical activity. Give an introduction to the used software (e.g. EstlCAM or Fusion360), highlighting 2.5D milling features

Step 2: Students use the CAM software to prepare a toolpath for a 2.5D milling operation, including cutouts, drilled holes, tabs and engraving, starting from a 3D model prepared for this task. Presents parts of the workflow and asks students to repeat it.

Step 3: Use milling simulation for a preview of the toolpath.

Step 4: Students present the results of their work, discussion of problems and pitfalls

Activity 3 - Practical activity - CAM preparation of a 3D milling operation (8 hours)

Step 1: Present students with an overview of the practical activity. Give an introduction to the used software (e.g. EstlCAM or Fusion360), highlighting 3D milling features

Step 2: Students use the CAM software to prepare a toolpath for a 3D relief milling operation, including a roughing and a finishing path, starting from a 3D model prepared for this task. Present parts of the workflow and ask students to repeat it.

Step 3: Use milling simulation for a preview of the toolpath.

Step 4: Students present the results of their work, discussion of problems and pitfalls

Activity 4 - Practical activity - CAM preparation of a 2.5 milling operation

Step 1: Present students with an overview of the practical activity. Give an introduction to the used software (e.g. EstlCAM or Fusion360), highlighting 2.5D milling features

Step 2: Students use the CAM software to prepare a toolpath for a 2.5D milling operation, including cutouts, drilled holes, tabs and engraving. Presents parts of the workflow and asks students to repeat it.

Step 3: Review of work, discussion

Tools and materials needed: PCs, CAM software

Learning Outcomes acquired:

- S2 To prepare 3D Models for CNC production

Assessment methodology: the achievement of the learning outcomes will be assessed through the evaluation of the work realized by the students.

Profile 7. Robot machines technician for Industry 4.0

Competences acquired

C7. Makes the setup, operation, and maintenance of a robotic machine for industry 4.0

Module 1. Robotics systems in the Industry 4.0.

Duration: 10 hours (2,5 hours each activity) EQF:4 ECVET: 0,4 C

Activity 1 - Introduction lecture - Overview on robotics and automation

Step 1: Present students with an overview of:

- definition and origin of robotics
- different types of robotics
- various generations of robots
- the basic structure of a robot
- Asimov's laws of robotics

Activity 2 - Group work - Types and functions of robots (and sensors) for robotic application

Step 1: Present students the types of applications of robotic solutions in Industry 4.0 and the brief sensor characteristic.

Step 2: Divide the students into 3 groups (the manipulation robotic system group, the mobile robotic system group, and the data acquisition robotic group).

Step 3: Ask groups to design a plan to apply a specific type of robot in an industry of their choice. The plan should also assume the potential benefits of the proposed solution and how the various sensors will be used.

Step 4: Lead and moderate the discussion, during which each group presents its plan for using robots in industry.

Activity 3 - Lecture and multimedia presentation - Human-robot interaction and collaborative robots

Step 1: Present students the basics of HRI:

- main features of human-computer interaction
- definition of artificial intelligence
- basic principles of NLU and learning psychology
- types of collaborative robots

Step 2: Show the students videos demonstrating the work and operation of COBOTS (e.g. Kuka, Rethink Robotics, ABB, Fanuc).

Step 3: Lead and moderate the discussion on the videos watched and HRI.

Activity 4 - Group work - Exam preparation

Step 1: Ask students to prepare questions for a quiz.

Step 2: Divide the students into two or more groups. Students are asked to compete in groups, trying to correctly answer the questions asked by the opposing group. The group with the most points wins.

Tools and materials needed: Laptop, projector, charts.

Sample literature:

- M. Gurgul, "Industrial robots and cobots: Everything you need to know about your future co-worker", Michal Gurgul, 2019.
- M. P. Groover, M. Weiss, R. N. Nagel, N. G. Odrey, A. Dutta, "Industrial Robotics: Technology, Programming and Applications", McGraw-Hill, 2017.
- J. J. Craig, "Introduction to robotics: Mechanics and control", 3rd Edition, Pearson/Prentice Hall, 2005.

Learning Outcomes acquired:

- K1 To describe robot components, characteristics and applications.
- K4 To list types of collaborative robots (collaborative, Anthropomorphic Systems, Cobots, etc...).

Assessment methodology: at the end of the module, students take an exam (based on the issues discussed in the activities, 60% pass threshold). Students from the group that won the quiz received an additional point to their exam score.

Module 2. Human-robot interaction

Duration: 60 hours EQF:4 ECVET: 2,2 C

Activity 1 - Robotic arm presentation (2h)

Step 1: Show students videos about robotic arms in Industry 4.0, giving them information about arm robots - kinematics and applications, type of movements (point-to-point, controlled, safe), Forward kinematics and Inverse kinematics, and different automation systems components such as an interpreter, path planner and path generator.

Step 2: Present students the industrial robotic arm components and their functionality.

Activity 2 - Presentation of the TINKERKIT-BRACCIO (2h)

Step 1: Present students the Thinkerkit Braccio components and their functionality such as the servos and the Arduino microcontroller.

Step 2: Introduce the Arduino IDE and programming language to the students.

Activity 3 - Group activity - the TINKERKIT-BRACCIO (14h)

Step 1: Divide students into groups of 4. The groups will explore the robotic arm and its functionalities.

Step 2: Ask each group to realize a specific task for the arm.

Step 3: Ask each group to present the result of their work to the class. The results will be tested and evaluated.

Activity 4 - Workshop session – industrial arm introduction (2, 3 students per machine, 100% supervision) 42h

Step 1: Show students how to program an industrial robotic arm to do basic tasks

Step 2: Show students how to setup and monitor an industrial robotic arm.

Step 3: Ask students to perform basic programming, setup and monitoring activities with the industrial robotic arm.

Tools and materials needed: The TINKERKIT-BRACCIO powered by Arduino, some PCs to install the Arduino programming language, an Internet connection to download examples and the Arduino IDE to be installed, Instruments to measure electrical quantities, an Industrial robotic arm

Learning Outcomes acquired:

- S1 To be able to program a robotic arm to do basic tasks.
- S2 To setup and monitor an industrial robotic arm.

Assessment methodology: The students are evaluated according to the following coordinates:

- observing their project work activities during mini hackathons
- testing their outcomes via quiz/questionnaire
- evaluating their group presentations

The teacher is going to evaluate not only hard skills but also soft skills such as creativity, leadership, teamwork, autonomy, etc.

Module 3. Risk analysis and design of robotic cells using cobots

Duration: 25 hours (12h of face to face or online classes and 13h hours of personal work) **EQF:**4 **ECVET:** 0,9 C

Activity 1 - Face-to-face presentation. Theoretical background (5 hours)

Step 1: Present students Robotic cells designs fundamentals

Step 2: Present student risk analysis management.

Step 3: Present students maintenance approaches.

Activity 2 - Group work for solving an industrial case of the study by simulation (8 hours)

Step 1: Introduce students to robotic cell simulation activity

Step 2: Divide students into small groups asking them to solve the risk analysis of the case of use.

Activity 3 - Group work studying an actual industrial case of study (10 hours).

Step 1. Show the students a description of the layout and elements of the robotics cell, focusing on Failure mode and effects (FMEA) analysis.

Step 2. Divide students into small groups to develop the FMEA analysis.

Step 3. Ask the groups to diagnose and solve a failure.

Activity 4 - Open discussion about the obtained solutions of activity 2 (2 hours)

Step 1. Ask each group to present the results (solutions found)

Step 2. Lead the discussion as a whole class on the basis of the results shown.

Step 3. Ask each group to evaluate the work done by the other groups using a checklist provided by the teacher.

Learning Outcomes acquired:

- K3 To list the advantages and disadvantages of collaborative robotics
- K6 To describe maintenance indicators and diagnostic techniques
- S3 To be able to detect risks and safety problems while a robot is running
- S4 To do basic maintenance operations

Assessment methodology: Evaluation of the quality and contents of the presentations - Final test.

Module 4. Advanced robot programming

Duration: 25 hours (12h of face to face or online classes and 13h hours of personal work) - EQF:4 ECVET: 0,9 C

Activity 1 - Face-to-face presentation - Theoretical background (10 hours)

Step 1. Present students the Industrial Robot programming foundations.

Step 2. Show students the Robot task geometrical model.

Step 3. Show the students the Industrial robot-specific programming languages.

Step 4. Show the students Off-line programming and simulation.

Activity 2 - Group work for solving an industrial case of study by simulation (8 hours)

Step 1. Present the students the case of study presentation based on typical robot activities

Step 2. Task model definition: Ask students to identify the working frames in order to realise the definition of the robot movements and object interaction.

Step 3. Guiding students in the development of the first robotic programme for task execution by means of offline robotic programming.

Step 4. Simulation and validation: Ask the students to debug the robot programme using robot simulation software.

Activity 3 - Group work for solving an actual industrial case of study (10 hours)

Step 1. Allow students time to study the workflow of a real robot cell to develop the geometric model of the tasks, following the methodology described in Activity 2, step 2.

Step 2. Guiding students in the development of the robot programming and communication with the other elements of the robotic cells to perform the specified tasks.

Step 3. Program validation: Ask the students to debug the robot program in the real cell by using the methodology described at Activity 2, step 4.

Activity 4 - Open discussion about the obtained solutions of activity 2 (2 hours)

Step 1. Ask each group to present the results (solutions found)

Step 2. Lead the discussion as a whole class on the basis of the results shown.

Step 3. Ask each group to evaluate the work done by the other groups using a checklist provided by the teacher.

Tools and materials needed: Internet connection, laptop, robot off-line programming and simulation software.

Learning Outcomes acquired:

- K2 To present what advanced and collaborative robots are and how they work
- K5 To present differences between collaborative robots and industrial robots

Assessment methodology:

- Evaluation of the quality and contents of the presentations.
- Final test.

Conclusions

The MakeMyFuture Modules as you could experience are focused on maker-based training path for VET students aiming to support the achievement of advanced digital competences in line with the needs of Industry 4.0.

These modules provide a collection of lessons to guide VET schools, teachers or educators who need to improve VET students' employability and access to the labour market in Europe, as well as to promote the inclusion and motivation of VET students, particularly those with low academic performance.

We have selected specific profiles, such as Additive Manufacturing Technician, CNC Operations Technician, CAD / CAM Technician and Robot Machines Technician to orient your teaching activities towards the profiles most in demand in Industry 4.0.

Through the modules, the teacher will be able to provide students with a range of digital skills for Industry 4.0 by exploiting technologies used in Fablabs and maker labs. This is because these tools are based on the same technologies used in advanced manufacturing industries.

We hope that many VET teachers are now encouraged to implement maker-based activities into their lessons soon, for providing VET students with advanced digital competences, in line with the changes of Industry 4.0.