Innovative Vocational Didactics Aimed at the Preparation of Staff According to Industry 4.0 and Europe 2020

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Abstract. The article presents the e-support methods for vocational learning process at three advancement levels, which can be useful for the preparation of staff according to Industry 4.0 concept and Europe 2020 Strategy. The authors present the application of the animation programmes, which are supportive for learning of CNC programming. They compare the way of learning with the use of real panels for the operator, which are the parts of an individual machine and the animation programme. In the article the authors show designed real didactic stands for e-learning process in the virtual laboratory. The architecture of the didactic stands is designed and it is based on the National Qualification Frameworks (NQF), educational requirements and the requirements of the labour market. The didactic stands aim at learning of PLC programming (Programmable Logic Controller) and HMI (Human Machine Interface). With the use of the PC and the Internet, it is possible to steer a real object, to programme research tasks and to verify the correctness of the tasks undertaken. The didactic stands are independent and autonomous, and equipped with the protection driver. The result of the learning process is to gain skills by students, which are strictly linked with the execution of tasks in a real labour environment.

Introduction

The new approach to vocational education process requires to undertake activities within 4.0 Industry [1] Europe 2020 strategy [2], for which the intelligent development of knowledge based economy is the priority. This includes initiatives, which introduce automatics and robotics. It is very important to improve technology [3] and to modify construction and tool materials [4], and minimisation loss of energy [5]. It is predicted to steer technological stands virtually with the use of the Internet. The Factory of the Future will employ lower number of workers. It is a big challenge for vocational education, which should be based on innovative digital simulations of future work stations.

The support of the vocational process depends on required qualifications on work stations [6]. The basic level (for physical workers) concerns knowledge and skills, which are elementary and indispensable for using technological object. It requires qualifications at lower level of EQF & NQF—basic knowledge and theoretical skills. It concerns such activities as the maintenance of a work station, the indication of any dangerous states and critical parameters, knowledge on the criteria of the assessment process, etc. At this stage, after observing any critical parameters, a worker should usually stop the process and give the relevant information to the manager. A worker does not decide and does not try to solve the problem on his/her own. The execution of vocational tasks at the technician level requires to react on the problem and therefore, e.g. a worker must change the parameters as they must be accepted, and assess the whole process. Any preventive measures should be found out and the critical parameters must be accepted. In the first case, the PC with animation programme is sufficient for learning. In the second case, the didactic stand must be equipped with the machine panel for the operator or its simulator.

In order to learn how to use or to design more complex processes or devices at the engineering level, it is necessary to have the access to more advanced didactic stands. The on-line learning in the
virtual laboratory is a very innovative method [7]. The didactic virtual laboratory enables the students to use real objects in a selected time and it enables them to verify acquired knowledge and skills. In order to design the virtual laboratory equipped with e-learning real didactic stands for vocational and continuing education, the authors considered the European and the National Qualification Frameworks [8, 9] and vocational education standards [10, 11]. The designed real didactic stand for the virtual laboratory aims at developing and programming mechatronic devices and systems [12]. The learning outcome will be the acquisition of the following skills: the design of the technical documentation for mechatronic devices and systems; the design of mechatronic devices and systems; the programming of mechatronic devices and systems.

Didactic Stands of the Basic E-support for the Learning Process on the Example of CNC Programming

The basic stand for learning CNC programming is the PC equipped with the animation programme. After preliminary learning of the language adequate for CNC programming, a student verifies acquired practical skills through observing the movements of tools on the PC screen. The programme for the treatment, consisting of activities such as the exchange of tools, the adjustment of adequate machining speed, the tool speed as a whole and the tool speed in the system of coordinates of the machine, is introduced from the keyboard. Figure 1 presents the screen of the animation programme.

Figure 1. Screen of the animation programme for the treatment of the roller on CNC lathe.

After introducing the programme, a student starts doing the activities through observing the programme on the screen. The picture on the screen is the same as in the reality. The simulation can include technological parameters and it can be relevant to the real time of the treatment or to work summarily. When prohibited movement of tools, speed, collision with the objects or with the elements of the machining appear, it is immediately visible on the screen in the form of announcements. A student must correct the programme as it must be accepted by the animation programme. The presented didactic stand is of a universal character and it considers, among others, the correctness of the designed technological programme and it can be applied at the preliminary stage of vocational education and training for a specified group of machines, e.g. lathes and milling machines. The elements, which are characteristic for any individual type of the machines, are not taken into account and therefore a student, after completing the course, can have problems with the service of a specific machine.

Figure 2 presents the didactic stand for technological programming of the machine tools with the consideration of characteristic features of any individual machine. The didactic stand contains HMI panel for the operator or its simulator, which are shown on the screen.
The didactic stand can be used in two variants: with virtual HMI panels for the operator, which are adequate for several machines, and which are shown on the screen or with a real panel, which is identical with the operation panel adequate for an individual machine. A student designs the technological programme. Next, a student starts working through the use of HMI operation panel, which is the same as in the real machine. The animation programme simulates the work of the machine tool according to the technological programme designed by a student with all consequences of errors. Several strategies for learning are possible. The basic version is that the course of tools and the stop of the programme are shown on the screen if the first error with no announcements appears. A student must find error and correct the technological programme. The simulation of the process lasts till the moment of finding the first error. Another learning strategy is to give the announcement, which concerns the reasons and places of errors. The advantage of this method is that a student is able to learn the service of a tangible HMI panel of the machine, which will be used in future work.

The Concept of the Real Didactic and E-learning Stand for the Virtual Laboratory

The didactic stand for e-learning of PLCs programming consists of the user controller (PLCu) and paralleled protection controller (PLCs). The concept is illustrated in Figure 3 [12]. The controller, CCD camera and optional HMI panel interface are equipped with RJ45 connectors (Internet) and plugged into the router to the server. The user of the stand introduces the programme to the PLC and, by using a CCD camera, observes the way the program runs. Specialised Learning Content Management System software, placed on the user server, manages the access to both the stand and learning process.

The protection PLC controller monitors the interoperability of the user program in the user controller PLC and detects dangers for the stand conditions, e.g. activation of limit switches, exceeding the temperature limit values, emergencies, etc. The occurrence of an unsafe condition is signalled with a red light and the possibility to start the heater is blocked, e.g. when the temperature is exceeded. Therefore, the protection controller detects critical conditions in controller and blocks the user controller activity. The protection PLC controller impacts are invisible to the user during the programme execution till the moment of the occurrence of dangerous states. When occurring dangerous state, the announcement is generated and the user must solve the problem.
Figure 3. The concept of the stand for e-learning of PLC programming.

Figure 3 also shows a hardware and a computer structure of the stand for e-learning in the virtual laboratory.

Construction of the E-learning Didactic Stand on the example of Technological Transport Line for Sorting

Figure 4 presents the model of a real technological transport line aimed at learning of PLC programming and steering in a virtual laboratory. The technological line consists of two conveyor belts set in the 2U layout on which the rotating modules, aimed at sorting, circle in a closed system. The line includes inductive, laser and ultra-sound sensors and such elements as a stepper motor, AC and DC motors, pneumatic actuators. The sectors, which are significant from the point of view of a stand activity, are monitored by the cameras. The architecture of a didactic stand enables, with the use of the Internet, remote audio-video observation in a realistic time, programming and process steering.

Rotating modules with stepper motors and encoders were applied as sorting elements 1 and 2. Mini pneumatic actuators 3 and 4 were applied for transmitting sorting elements between lines.

Line drives with synchronous motors M1 and M2 were replaced by DC motors 24VDC with PWM speed controllers—it enables the user to control easily the speed of the line. Sorted items in a cylinder shape are placed in standard pallets. Items are arranged according to the following criteria: colour, height, type of material.

Execution of Tasks at the Didactic Stand

The management system makes the following elements available: exemplary programmes, scheme of a stand, documentation of the PLC and HMI panel and the instruction how to execute tasks.
The user, after logging in the e-learning management system, sees a laboratory stand with the PLC and HMI operator panels on the screen. The user has an access to the utility programmes (programming software for the PLC and HMI operator panel). The utility programmes can be installed on a user's computer or shared by the management system.

In the reality, the stands are equipped with a much greater amount of hardware and software. The protection controller is not visible for the user.

The constructed stand for e-learning of PLC programming of technological transport enables the students to: remote observation of the experiment (audio-video); remote visualisation of the experiment in real time; control of the experiment course–remote control of the experiment, and to have the access to apparatus located in another place.

Summary

The concept of the e-learning stand on the example of the technological transport line, presented in the paper, enables the students to steer the object, its observation, audio-video, configuration and control of technological functions of the object. Remote access to rich apparatus resources of training institutions gives to the user the possibilities of the improvement of qualifications and training in a non-formalised time (night hours, days out of work, etc.).

E-support for vocational didactics can be performed at different advancement levels. The basic courses (courses for physical workers and re-qualifications) can be performed through delivering didactic materials to students. Afterwards, a student is able to check his / her progress on the own PC. It is necessary to observe the picture on the monitor, which is the same as the real work station.

The e-learning course in the virtual laboratory requires from a student higher level of knowledge and skills and it is very effective in engineering studies. The main aim of programming and steering of the objects is to meet IT systems, which are applied in innovative enterprises. Such companies require the introduction of quick changes in programming and steering of technological machines. These activities are included in Industry 4.0 concept, which aims at full integration of machines and devices with management production systems and Internet of Things –IoT concept aiming at the need of exchanging a high amount of information and data, which should be accessible to other applications and devices [13]. Therefore, the priorities of the Europe 2020 strategy are the following: intelligent development of economy based knowledge; sustainable development and the support of economy with high rate of the employment.

The use of the virtual laboratory enables the students to improve qualifications (as qualified courses), which are required at the labour market, through e-learning education and e-learning. The curriculum of such training should consider the requirements of the labour market on current demand of vocational qualifications, educational standards and vocational competence standards.

References


