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Innovation of University Courses in The Field of Manufacturing Technologies Based on The Implementation of Dual Education

Nedeljko Dučić [1*], Jelena Baralić [1], Radomir Slavković [1]
[1] University of Kragujevac, Faculty of Technical Sciences Čačak, Serbia
[*] nedeljko.ducic@ftn.kg.ac.rs

Abstract: *In this paper is presented the project that was realized within the framework of the activity "Development of higher education". The project is supported and financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia. The project is a set of activities to improve theoretical and practical content of teaching cources belonging to the field of manufacturing technologies, through the implementation of dual education. Teaching cources, whose improvement is the aim of the project, exist on the bachelor and master studies Mechatronics at the Faculty of Technical Sciences Čačak.*

Keywords: *higher education, manufacturing technologies, practice, dual education*

1. INTRODUCTION

Technical faculties around the world pay great attention to the careers of their students [1,2]. One of the segments of this process is the organization of professional practices and visits to the industry during the studies.

Many researches deal with the presence of practice in the curriculum. Chen et al (2012) presented the integration of theoretical knowledge and hands-on experiment to solve proposed problems, and thus have drawn great attention worldwide. As one of the typical and innovative teaching modes in mechatronics in China, mechatronics teaching in Beihang University has formed a "One main line, two links, three practical points" mode and methodology, which emphasizes on the links and mapping relationships between theoretical teaching and practical teaching [3]. Cohen and Katz (2015) point out that mechanical engineering (ME) curriculum does not include courses that teach ME students essential professional knowledge needed to become a design engineer [4]. Loschilova et al (2015) presented a pedagogical model of professional training of bachelor's in mechanical engineering based on networking, which facilitates the demand for graduates in labor market was designed [5]. Suzdal et al. (2015) presented the consideration of the problem of qualified engineering personnel training in the mechanical engineering industry [6]. Hoernicke et al. (2017) presented the importance of exchanging between industry and academia. One effective but not often considered form of exchange is inclusion of guest lectures by industry experts in the syllabus [7].

The idea of the project presented in this paper is the integration of industrial practical activities of students into the teaching process. The overall objective of the project is to innovate a group of existing teaching courses in the programs of university courses of the bachelor and master studies of Mechatronics. Innovation will include a group of courses belonging to the scientific field of Manufacturing Technology, four courses in bachelor studies and one course in master studies. The planned courses for innovation on bachelor studies are: CAD/CAM technology, Program control of machines, Unconventional technologies and Technological processes. Master studies will offer an improved course New manufacturing technology. Innovating of a group of courses will encompass several individual goals that belong to a group of program objectives of the Ministry of Education, Science and Technological Development of the Republic of Serbia. Innovating will involve the improvement of theoretical and especially practical content of the courses through intensive and detailed planned cooperation with the industry. This will improve the competencies of teachers and associates and raise the quality of the educational process through creating better conditions for the realization of teaching. Cooperation with the industry will enable the implementation of the concept of dual education through well-organized practices. Each of the improving courses will include industry practice, within which one project will be implemented. Projects realized within practice will be evaluated with a certain number of points. Implementation of dual education will present to business entities, in which the practice is realized, the potential of students and it will open the possibility of their employment upon completion of studies. In this way, the innovative programs of university courses, through a strong correlation with the industry, will respond to the needs of the labor market in the field of industrial production.

2. PROJECT ACTIVITIES

Project activities (there are nine in total) are defined by the set of project objectives. Their realization is planned within five months, as needed for the project realization.

The first activity (A1) contains an analysis of the content of the same or similar courses at the programs of university courses at prestigious world technical faculties. Related courses were analyzed at the following twelve universities around the world: Faculty of Engineering Science and Technology/UiT The Arctic University of Norway (Tromso, Norway), Swinburne University of Technology (Melbourne, Australia), Faculty of Science, Engineering and Computing/Kingston University (London, England), Greenville Technical College (Greenville, USA), Hennepin Technical College (Minnesota, USA), Department of Mechanical Engineering National Institute of Technology Karnataka (Karnataka, India), Department of Mechanical Engineering, Faculty of Engineering/University of Sheffield (Sheffield, England), University of Nottingham (Nottingham, England), Michigan Technological University (Michigan, USA), Brno University of Technology/Faculty of Mechanical Engineering (Brno, Czech), University of Ottawa/Faculty of Engineering/Department of Mechanical Engineering (Ottawa, Canada), SMU/Lyle School of Engineering (Dallas, Texas, USA).

The second activity (A2) contains the analysis of software tools used in teaching processes from the same or similar courses at the programs of university courses of prestigious world technical faculties.

The third activity (A3) contains the analysis of practical teaching applied within the same or similar courses at the programs of university courses of prestigious world technical faculties. Practical teaching were analyzed at the following universities: University of Coventry (UK), Faculty of Mechanical Engineering, University of Texas (USA), University of Toronto (Canada), Faculty of Mechanical Engineering, McGill University, Montreal (Canada), University of South Australia, Adelaide (Australia).

The fourth activity (A4) contains an innovation of theoretical contents of teaching courses in accordance with contemporary and generally accepted literary sources.

The fifth activity (A5) includes the alignment of theoretical and practical teaching, and the formation of a work plan for working weeks.

The sixth activity (A6) includes detailed planning of practical teaching.

The seventh activity (A7) encompasses a trial one-month practical training in the industry with a selected group of students.

The eighth activity (A8) contains a detailed analysis of the realization of practical teaching.

Finally, the ninth activity (A9) contains potentially corrective action in the formation of the content of the innovated courses. The realization overview of these activities is given in Table 1.

Table 1. *Realization of activities (A) by months (M)*

	A1	A2	A3	A4	A5	A6	A7	A8	A9
M1	x	x	x						
M2	x	x	x	x					
M3					x	x			
M4							x		
M5								x	x

3. PRACTICAL TEACHING

After realization of activities A1-A5, detailed planning of the practical teaching courses (CAD/CAM technology, Program control of machines, Unconventional technologies and Technological processes and New manufacturing technology) was conducted. One-month practical training was realized for the course CAD/CAM technology. The students of the fourth year of the bachelor studies of Mechatronics realized the trial practice. Ten students realized a practical part of the teaching process in the company "Sloboda" A.D. Čačak. Practical teaching were organized in four blocks.

Content of the first block of practical teaching is design of technology for making work on CNC milling machine. Applied technological sequences: surface milling, profile milling, volume milling, hole making. Expected outcomes of the first block of practical teaching:

1. Students successfully follow and understand segments of teaching related to practical work.

2. Students acquire knowledge and gain the ability to independently design the required technological sequences.

Content of the second block of practical teaching is: Creating of a CL file (CUTTER LOCATION FILE). Postprocessing. Making work on CNC milling machine. Expected outcomes of the second block of practical teaching:

1. Students successfully follow and understand segments of teaching related to practical work.
2. Students acquire knowledge and ability to independently generate a file containing the

tool path and post-presetting for the appropriate control unit.
3. Students create documentation with their activities.

Content of the third block of practical teaching is design of technology for making work on CNC turning machine. Applied technological sequences: turning, facing, grooving, thread making. Expected outcomes of the third block of practical teaching:

1. Students successfully follow and understand segments of teaching related to practical work.
2. Students acquire knowledge and gain the ability to independently design the required technological sequences.

Content of the fourth block of practical teaching is: Creating of a CL file (CUTTER LOCATION FILE). Postprocessing. Making work on CNC turning machine. Expected outcomes of the fourth block of practical teaching:

1. Students successfully follow and understand segments of teaching related to practical work.
2. Students acquire knowledge and ability to independently generate a file containing the tool path and post-presetting for the appropriate control unit.
3. Students create documentation with their activities.

After a one-month practice, students evaluated the practice in the form of a survey. Every block of practice was evaluated, and the overall rating was generally satisfaing. The conducted analysis through the A8 activity gave a clear demonstration of the success of the trial practice and marked the parts to be corrected. The degree of autonomy of students during practice is the most important segment that needs to be improved by the joint action of teachers and mentors in the industry. The general conclusion is that this segment should be improved through the establishment of practical project tasks, which are in line with current manufacturing programs of the company.

4. INNOVATED TEACHING COURSES

In this part of the paper, an overview of the innovated teaching courses is given, within the framework of the realized project. Improvements to the teaching courses are based on introduction of industry practice as a part of teaching process. In this way, the concept of dual education has been promoted, with a significant impact on practical activities within the teaching course.

4.1. CAD/CAM technology

Objective of teaching course. The main goal of the course is mastering computer technologies for modeling products in order to support production processes (CAM). Students acquire knowledge in the field of 3D modeling of products, design of manufacturing processes using modern software packages and creating postprocessor code for CNC machines.

Learning outcomes. Students will be trained in creating a 3D solid model of finished products, working models necessary for designing manufacturing processes, designing manufacturing processes, generating postprocessor code and corresponding technological documentation.

Contents of theoretical teaching. Basic of CAD/CAM technology. Principles of CAD/CAM design of technological processes. Technological design bases (technological sequences, technological parameters, etc.). Systems of tools in CAD/CAM technologies. CAD systems: modeling and visualization, parametric modeling, types of geometric models, wired, surface and solid models as the basis for generating tool paths, creating 3D models, reference and work models as the basis of CAM systems. CAM systems: work setting, production setup, define NC sequences, generation of data paths, and NC data documentation. CAM technology is being studied for follow machining processes: turning, milling and drilling.

Contents of practical teaching. Exercises in a computer classroom using CAM/CAM software packages. Practical part of teaching in industry.

Knowledge check. Knowledge testing involves several activities that participate in the final assessment, which are: activity during classes (5%), realization of tasks in computer exercises (25%), project in industry (40%) and oral part of the exam (30%).

4.2. Program control of machines

Objective of teaching course. The objective of the course is to acquire knowledge about: control of machine systems, program and adaptive control systems, elements of program and adaptive control techniques, their application, and especially for machine tools with CNC control. As a further logical step, students should master the basic methods of technological preparation, and in particular the methods of programming machine tools with CNC control.

Learning outcomes. Students will gain knowledge of machine tools, applied control systems, and especially machines based on CNC technology. Students will also be trained in programming machine tools with applied CNC control in the technology of turning, milling and drilling etc.

Contents of theoretical teaching. Mechanical systems with control shafts, copier systems, cyclical systems and numerical control systems, i.e. conventional (NC), computer numerical control (CNC) and distributive numerical control (DNC). Adaptive control (Adaptive Border Control Systems - ABCS and Adaptive Systems of Optimal Control - AOC). Numerical control elements (CNC control units, drive systems, machine tools as a control object and measuring systems). Application of CNC technology for machine tools (lathes, milling machines, drills, machining centers, plastic deformation machine tools, ultrasonic processing machines, laser processing machines, machines tools with parallel kinematics, measuring machines etc.). Programming machine tools in NC code, APT machine programming system and basics of CAD/CAM methodology of machines programming.

Contents of practical teaching. Exercises in a computer classroom using software for different types of CNC machine control units. Practical part of teaching at industry.

Knowledge check. Knowledge testing involves several activities that participate in the final assessment, which are: activity during classes (5%), realization of tasks in computer exercises (25%), project at industry (40%) and oral part of the exam (30%).

4.3. Unconventional technologies

Objective of teaching course. The main objective of the course is to familiarize students with technological processes of metal and non-metal processing in unconventional procedures for obtaining finished products (Ultrasonic Machining (USM), Abrasive Jet Machining (AJM), Water Jet Machining (WJM), Abrasive Water jet Machining (AWJM), Electrical Discharge Machining (EDM), Electron Beam machining (EBM), Plasma Arc Machining (PAM), Laser Beam Machining (LBM)...). Through lectures, exercises and project design, students are trained to apply theoretical and practical knowledge in the realization of various unconventional technologies.

Learning outcomes. Students gained the necessary theoretical and practical knowledge from Unconventional metal and non-metal processing technologies. They are able to: recognize and distinguish certain unconventional processing methods and the corresponding technological parameters, define the technological process of manufacturing for simpler practical examples.

Contents of theoretical teaching. Unconventional Machining Processes. Ultrasonic Machining (USM), Abrasive Jet Machining (AJM), Water Jet Machining (WJM), Abrasive Water jet Machining (AWJM), Electrical Discharge Machining (EDM), Electron Beam machining (EBM), Plasma Arc Machining (PAM), Laser Beam Machining (LBM). Comparison of unconventional machining processes and characteristics of treated areas.

Contents of practical teaching. At auditory exercises students determine the acquired theoretical knowledge. Part of the exercise is done in a laboratory for machine processing on a laser engraving machine. Students are trained to define technologies and procedures for the manufacturing process. Practical part of the teaching is at the industry where students are introduced to the selection and work of machines, accompanying equipment and defining and selection of processing parameters.

Knowledge check. Knowledge testing involves several activities that participate in the final assessment, which are: activity during classes (5%), realization of tasks in auditory exercises (20%), project at industry (30%) and oral part of the exam (45%).

4.4. Technological processes

Objective of teaching course. The main objective of the course is to familiarize students with all technological processes of metal processing in conventional methods of obtaining finished products (cutting and deformation processing). Through lectures, exercises and project design, students are trained to apply theoretical and practical knowledge in the realization of various technological processes.

Learning outcomes. Students gained the necessary theoretical and practical knowledge from the technological processes of metal processing. They are able to: recognize and differentiate the individual processing operations and the corresponding technological parameters, define the technological process of manufacturing for simpler practical examples.

Contents of theoretical teaching. Technological process. Basics of cutting. Processing procedures (turning, drilling, milling, grinding, thread making, etc.). Theoretical basis of the deformation processes, stresses, deformations, velocities etc. Processing of sheet metal by separation. Sheet metal processing bending. Deep drawing. Volumetric design. Technological processes and control, technological documentation.

Contents of practical teaching. Laboratory exercises are performed in a laboratory for machine processing. Students are trained to define technologies and procedures for product development, tools, machines, processing parameters and creating technological documentation. Practical part of teaching in industry.

Knowledge check. Knowledge testing involves several activities that participate in the final assessment, which are: activity during classes (5%), realization of tasks in auditory exercises (20%), project in industry (30%) and oral part of the exam (45%).

4.5. New manufacturing technologies

Objective of teaching course. The main objective of the course is to introduce students to the basics of rapid prototyping, as well as to learn about the technologies realized within the CNC system (computer numerical control), DNC (distributive numerical control), FMS (flexible manufacturing systems), ITS (intelligent technology systems).

Learning outcomes. Students gained the necessary knowledge of the rapid prototyping technology and technologies that are realized within the CNC system, DNC system and FMS system.

Contents of theoretical teaching. Rapid prototyping technology, CNC system (computer numerical control), DNC (distributive numerical control), FMS (flexible manufacturing systems), ITS (intelligent technology systems).

Contents of practical teaching. Practical part of teaching is realized in the industry and in the laboratory.

Knowledge check. Knowledge testing involves several activities that participate in the final assessment, which are: activity during classes (5%), project in industry (50%) and oral part of the exam (45%).

5. CONCLUSION

The paper presents realization of a project that showed great importance of practical teaching for subjects in the field of production technologies. Initiation of practical teaching, i.e. students' visits to the industry, significantly improved the teaching process and increased students' interest and motivation. The success of the students who have implemented the practice is best represented through passing the exam. During the examination period after the realization of teaching course in the field of CAD / CAM technology, all students (ten of them) who participated in implementation of probationary practical training passed the exam. Their achievement in the exam is as follows: three students got grade 10 (ten), which is the highest grade in higher education institutions in Serbia, two students got grade 9 (nine) and five students got grade 8 (eight), i.e. their average grade was 8.80 (eight and 80/100).

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